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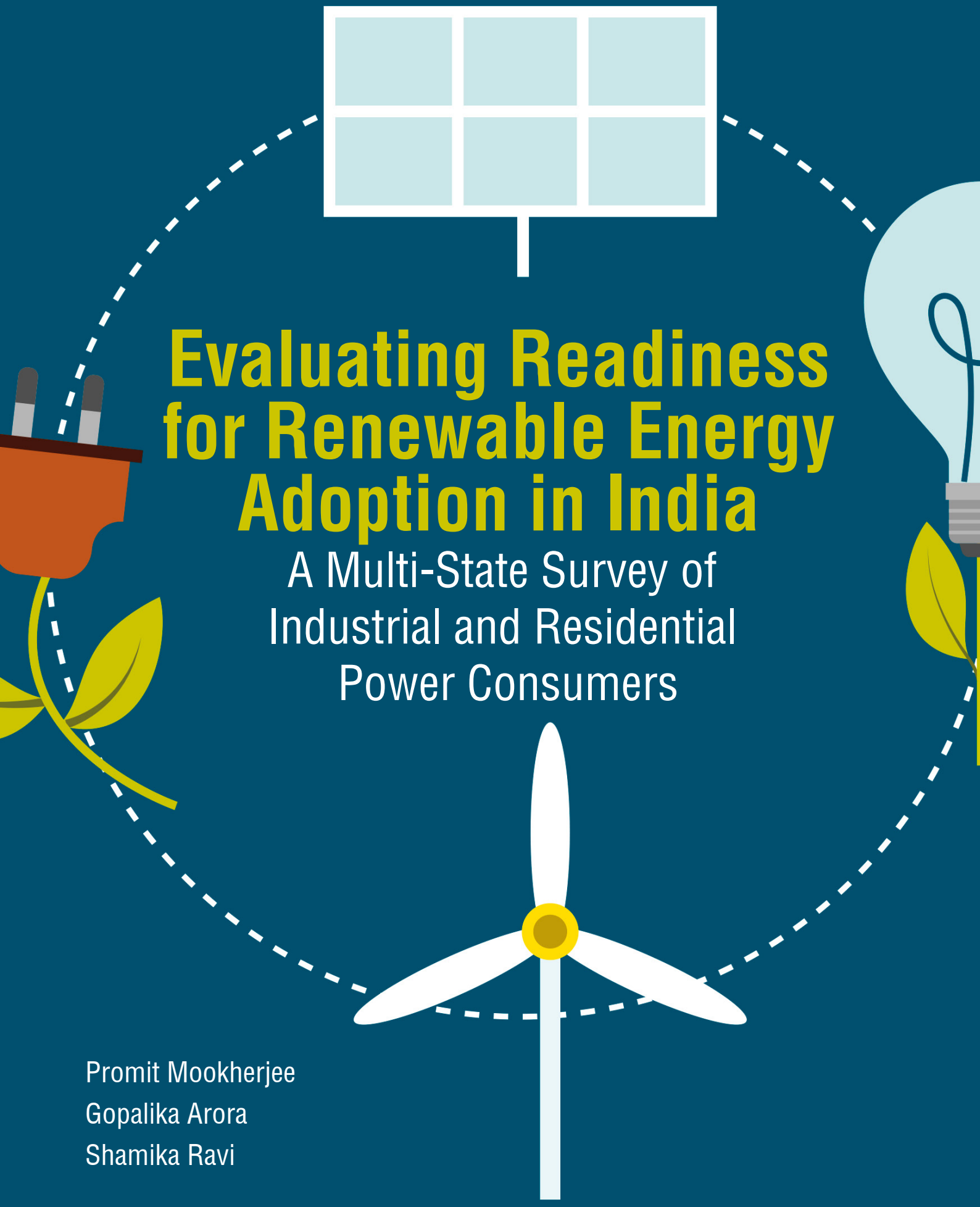

Evaluating Readiness for Renewable Energy Adoption in India

A Multi-State Survey of Industrial and Residential Power Consumers

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Executive Summary

India's significant strides in expanding its renewable energy sector have been driven by utility-scale projects. As the nation targets 500 GW of installed renewable capacity by 2030, the role of decentralised solutions such as rooftop solar (RTS) will have to be increasingly prioritised. Power consumers in the residential, commercial, and industrial sectors will also need to play a greater role through active adoption of renewable energy. However, consumers continue to face challenges in transitioning from being passive grid consumers to becoming active adopters of renewables. The slow growth of RTS (only 12 GW of the 40 GW target has been met so far) highlights the significant existing barriers, which current policies and incentives have been unable to adequately address.

While several studies have highlighted the techno-economic benefits of decentralised renewable energy solutions, this study aimed to understand consumer perceptions through an extensive on-site survey. The main goal is to understand how different groups of electricity consumers perceive the key technical, informational, policy, and regulatory obstacles that hinder the adoption of renewable energy sources. By bridging the gap between the on-ground realities and the prevailing narratives emerging from top-down assessments, this study has identified the key interventions required to improve consumer acceptance of renewable energy and spur greater adoption of the energy source.

Study Objectives and Research Questions

- To understand the key technical, informational, policy, and regulatory bottlenecks for adopting renewable energy, as perceived by different electricity consumer groups.
- To identify areas of intervention that can resolve the real challenges being faced by consumers.

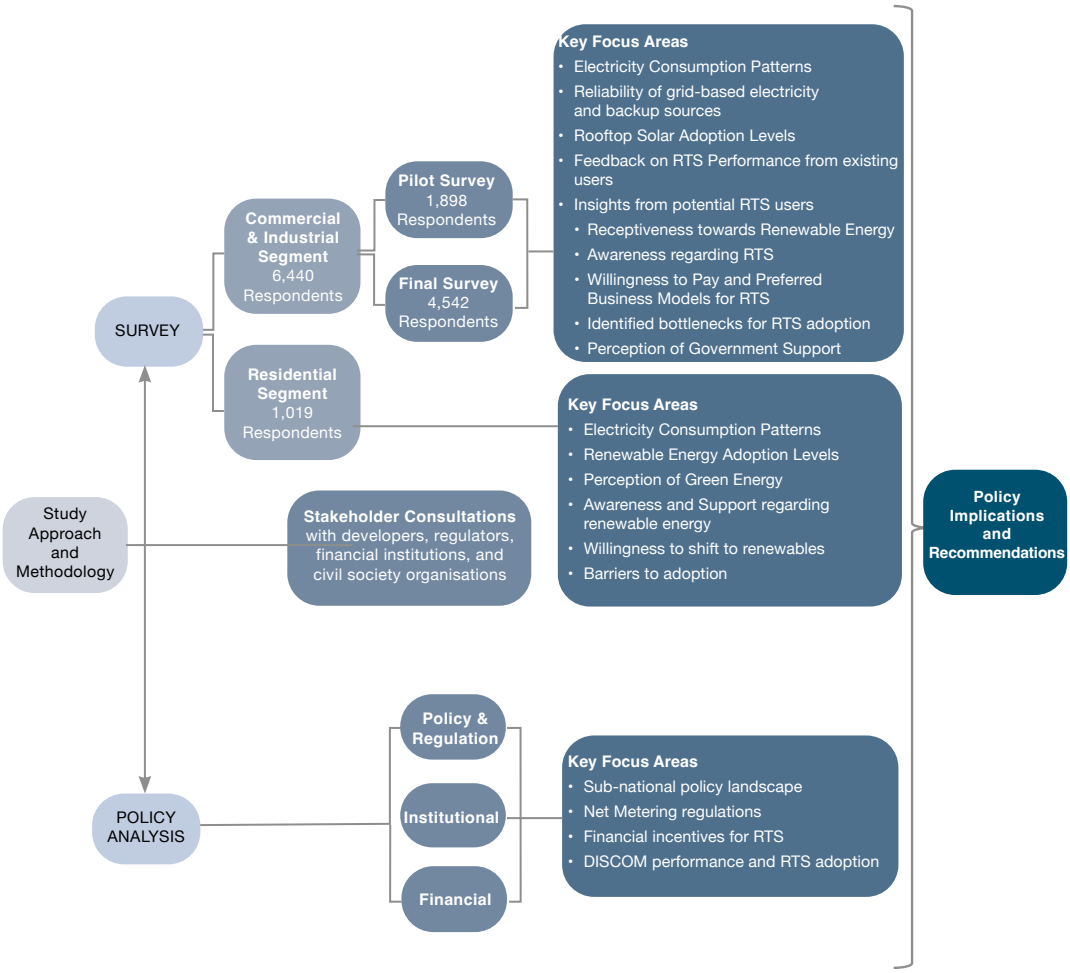
The study seeks to answer the following questions:

- What is the extent of rooftop solar adoption in different consumer segments, and what are the characteristics of existing users?
- What is the perception and willingness to pay for rooftop solar among power consumers who are yet to switch to renewable energy technologies?
- What are the major perceived barriers to rooftop solar adoption, and how effectively do existing policies address these barriers?
- What are the present electricity consumption patterns for different power consumers, and what do they imply for renewable energy adoption?

Study Approach and Methodology

This study implemented a systematic survey of approximately 7,500 respondents across both the residential and industrial power consumers in six states in India—Uttar Pradesh, Maharashtra, Gujarat, Tamil Nadu, Karnataka, and Andhra Pradesh. To contextualise the survey findings and address policy challenges, the study also analysed national- and state-level regulations concerning renewable energy adoption, with an emphasis on RTS.

Overview of methodology



Key Survey Findings: Commercial and Industrial Segment

Since previous studies have focused largely on the residential segment, this study prioritised commercial and industrial (C&I) power consumers. A sample of 6,524 C&I consumers were surveyed. The sample was stratified based on the National Industrial Classification (NIC) codes, and the distribution was taken based on the Annual Survey of Industries (ASI) 2018. The final sample included MSMEs as well as larger industries.

Electricity consumption patterns

- Significant differences in electricity expenditure were observed between industries. Large industries spent around INR 84 lakh per month on average, while the smallest enterprises spent INR 0.84 lakh. Electricity costs constituted 3 percent of total operational costs on average, with smaller industries spending a higher proportion to electricity expenses.
- The average daily electricity requirement across the sample of industrial units was 11 hours, with larger industries needing up to 17 hours.
- On average, 75 percent of electricity consumption occurred between 9 am and 4 pm for MSMEs, indicating substantial potential for renewable energy adoption even without requiring expensive battery storage solutions.

Reliability of grid-based electricity and backup sources

- **Prevalence of power cuts:** The majority of the sample faced frequent power cuts that affected business operations, with only about 20 percent reporting no power cuts. Uttar Pradesh had the highest incidence, with 76 percent experiencing daily power cuts, followed by Andhra Pradesh and Gujarat, which had less frequent yet significant interruptions.
- **Usage of DG sets:** Approximately 47 percent of the sample used DG sets for backup power, with significant variations across states. Tamil Nadu, Karnataka, and Uttar Pradesh had over 90 percent DG-set usage, while Gujarat and Maharashtra had less than 25 percent. The majority (83 percent) of DG-set users relied on large sets above 100 KVA, indicating the crucial role of DG sets in business operations during power outages.

RTS adoption levels

- In the overall sample, 3 percent of respondents utilised RTS, with the highest prevalence in Gujarat (9 percent), followed by Uttar Pradesh (3 percent), Maharashtra (2 percent), and Andhra Pradesh (1 percent). Tamil Nadu and Karnataka had no reported RTS usage.
- Medium-sized enterprises with annual revenues between INR 50 crore and INR 250 crore showed the highest adoption rate (7 percent), while the lowest adoption was in the revenue segment below INR 5 crore. Only 3 percent of respondents in larger industries, with an annual turnover above INR 250 crore, reported using RTS.

- Industries with high RTS prevalence included machinery and equipment manufacturing, pharmaceuticals, basic metals, chemicals, and fabricated metal products.

Insights from existing RTS users

- A majority of the RTS users were found to be medium- to long-term users of solar, with the average age of the RTS system ranging from 4.38 years in Uttar Pradesh to 6.5 years in Andhra Pradesh.
- Around 88 percent of the RTS users had systems connected to the grid. Only 30 percent of the users had some form of battery storage, with these users being concentrated in the larger industries.

- **Feedback on RTS performance from existing users:**

  - **Cost savings:** Across the sample, respondents rated their electricity cost savings from RTS with an average score of 3.4 out of 5, indicating only moderate satisfaction. Larger industries expressed low satisfaction with RTS cost reductions, challenging the narrative of substantial long-term net cost benefits. Even long-term RTS users did not perceive significant cost savings near the expected cost breakeven point.
  - **Operation and maintenance (O&M):** This remains challenging for adopters, despite major maintenance tasks being handled by developers or O&M companies. Satisfaction with ease of maintenance is generally low, especially for larger industries with higher RTS capacity.

Insights from potential RTS users

- **Willingness to shift to renewables:** More than 65 percent of the respondents across states and industries expressed a strong willingness to shift to renewable energy. Industries that reported the highest willingness to shift were computer electronic and optical products; furniture; motor vehicles; trailers and semi-trailers; paper products; rubber and plastic products; fabricated metal products; and textiles.
- **Preferred mode of adoption:** Respondents in most states (five out of six) reported a preference to purchase renewable electricity from the grid, closely followed by setting up an RTS system. Across all industrial segments,

respondents were evenly split between those who preferred to purchase renewable electricity from the grid and those who favoured installing RTS systems, with approximately 60 percent of the respondents opting for either choice.

- **Willingness to pay:** Across all industry segments, more than 60 percent of the respondents were not willing to pay extra for RTS. However, if they are willing, they would prefer making an outright purchase rather than an operational cost-based adoption model, as the respondents considered it to be cheaper in the long run.
- **Identified bottlenecks:**
  - Lack of financing options and the absence of specific subsidies for the C&I segment were identified as the major barriers to the adoption of RTS.
  - Most respondents also reported that their main reason for not making the shift to RTS was because they did not perceive any cost savings from its adoption.
  - Physical constraints were also identified as a key barrier.
  - For MSMEs, the lack of financing options was highlighted as a major barrier to the adoption of RTS. For larger industries, physical constraints also emerged as a major barrier.
- **Perceptions regarding government support**
  - The most preferred interventions to accelerate the adoption of RTS was the subsidisation of purchase cost, closely followed by the provision of low-interest loans.
  - There was also a demand for improved net metering regulations from all six states.

Key Survey Findings: Residential Segment

The survey also included a sample of 1,019 residential respondents spread over 40 cities across the six states included in the study.

Electricity consumption patterns

- Total electricity consumption correlated positively with average household incomes. The average monthly electricity expenditure across the sample was INR 1,400, with Karnataka (INR 1,829) and Tamil Nadu (INR 1,539) reporting the highest average expenditures.

- The survey revealed significant concerns about the reliability of grid electricity among residential consumers. About 71 percent of respondents experienced power cuts, with respondents in Uttar Pradesh and Maharashtra facing frequent daily power cuts. Gujarat had the lowest power-cut issues, while Andhra Pradesh reported the longest average duration, with 11 hours of power cuts per month.
- Residential consumers had lower utilisation of backup power sources like inverters or DG sets despite frequent power cuts. Only seven respondents reported using backups, which were mostly limited to higher-income households, indicating affordability issues for many.

Renewable energy adoption

- Renewable energy usage among residential consumers was even lower for residential consumers, with only five respondents (<1 percent) using RTS and no other solar-based appliances. This highlights the untapped potential of solar in the residential segment and the urgent need to accelerate adoption.
- The CAPEX-based purchase model was the most common among RTS users, with four out of five adopting this model, spending an average of INR 3.5 lakh. This preference for CAPEX was driven by a lack of awareness about OPEX models.
- Limited availability of RTS loans and high-interest rates (above 10 percent) were significant barriers, resulting in higher-income households adopting CAPEX.

Perception of Green Energy

- 64 percent of the respondents consider the transition to renewable energy to be an urgent policy priority, reflecting broad-based support for India's renewable energy transition.
- 67 percent of respondents stated the need for greater government incentives to promote green energy adoption.
- Solar energy had the highest awareness and support, followed by wind energy, reflecting their pivotal roles in India's energy transition.
- Surprisingly, natural gas garnered significant support and was viewed as a crucial transitional fuel in India's clean energy shift.

Willingness to shift to renewables

- Around 60 percent of the respondents expressed an interest in adopting renewable energy, with 25 percent showing a strong desire. However, Karnataka and Tamil Nadu displayed the lowest willingness to adopt renewables, despite their leadership in utility-scale renewable installations.
- Overall, respondents were evenly split between preferring to install RTS systems and purchasing renewable electricity from the grid. In Maharashtra and Gujarat, most respondents favoured setting up their own RTS systems, indicating the impact of existing adoption rates and proactive state policies in promoting renewable energy uptake.
- Only 24 percent of respondents were willing to pay a higher tariff for renewable electricity from the grid. In Maharashtra, support for the state's green premium policy was low, with only 16 percent agreeing to pay the premium.

Barriers to adoption

- Financial barriers, such as the high upfront costs and perceived low return on investment, hinder RTS adoption in this segment. Lack of access to OPEX financing models underscores the need for broader implementation to support residential consumers.

- Lack of awareness about evolving renewable technologies and available options poses a significant barrier to adoption. Many respondents expressed difficulties in identifying the most suitable technology, which remains a major barrier to adoption.

Policy Implications and Recommendations

Study Insights	Recommendations
Awareness regarding the long-term financial implications of adopting RTS remains limited.	Expanding the reach of digital tools for assessing the costs implications of RTS.
	Extending the scope of existing awareness tools to the C&I segment.
	Targeted information dissemination programmes in residential complexes and industrial clusters.
Persistent power cuts continue to disrupt industrial operations and lead to heavy reliance on polluting, diesel-based backup sources.	Targeted programs to establish RTS as a means to reduce dependence on DG sets.
The receptiveness towards RTS is high across consumer segments, but the willingness to pay remains low.	Reconsidering green premiums in favour of time-of-day tariffs to encourage adoption.
	Expanding the reach of low-interest loans for RTS adoption.
High upfront costs and the absence of easily accessible financing and incentives continue to be the primary perceived obstacles to the adoption of RTS.	Extending subsidies on RTS to C&I consumers.
	Greater role of utilities and development banks in reducing risk for financiers through risk-sharing mechanisms.
	Greater financial incentives for utilities to encourage greater adoption in the C&I segment.

MSME power consumption patterns are well suited for RTS, but there are several barriers to adoption.	Targeted focus on MSMEs in national and state solar policies.
	Cluster-based programme for MSME RTS adoption.
	Improving ease of obtaining necessary permissions and procedures for adopting RTS.
Acceptance and willingness to adopt the OPEX or RESCO-based financing model remains limited due to lack of awareness and accessibility.	Reducing risks for developers.
	Exploring the green bond market.
Benefits of net metering are difficult to access for both residential and C&I consumers due to technical limitations and procedural uncertainty.	Streamlining net metering regulations and procedures.
	Expanding virtual net metering and group net metering.

Setting the Context

At COP26 in 2021, Prime Minister Narendra Modi committed India to achieving carbon neutrality by 2070. The following year, India further demonstrated its dedication to the Paris Agreement by submitting its updated Nationally Determined Contributions (NDCs), whose crucial element involves the rapid expansion of renewable energy to achieve a remarkable 500GW of renewable capacity by 2030. This will require more renewable capacity addition in the next decade than India's current total installed power generation capacity.

In the short term, India had set itself a target of reaching 175GW of renewable energy by 2022. This included a goal of 100 GW from solar power, with 40 GW coming from rooftop solar and the rest from utility-scale solar. As of 30 August 2023, India has successfully achieved an installed solar capacity of 71.6 GW,[1] with an average annual addition of around 9 GW since the target was announced in 2015. This is particularly noteworthy for a developing country, and it positions India as the fourth largest nation globally in terms of installed solar capacity. Despite these achievements, however, India has yet to fully meet its targets, and a closer examination of the solar installation breakdown reveals a stumbling block: Of the total installed solar capacity, only around 11 GW has come from rooftop solar—one-fourth of the stated target.[2]

The promise of rooftop solar in India is immense; urban solar rooftop potential alone is estimated to be around 124 GW.[3] While governments, regulatory institutions, and project developers are the key stakeholders in advancing utility-scale solar projects, scaling up solar rooftop adoption will require existing consumers to shift from the grid to proactively adopting renewable energy solutions. This presents a pivot in the decision-making process for these consumers and will require the right policy incentives and signals to overcome the initial financial hurdles and internalise potential benefits in their decision-making. However, the slow growth of rooftop solar suggests that there remain significant gaps and barriers.

India has a number of policies for encouraging solar energy adoption—the National Solar Mission, the Grid Connected Solar Rooftop Programme, and the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana (PM-KUSUM) at the national level are complemented by state-level policies in a majority of the states in India. These schemes aim to solve the perceived technical, financial, and awareness barriers that hinder the adoption of renewable energy. Although these programmes have been in operation for some years now, there is a need to identify the specific reasons why policies for decentralised renewable energy have met with limited success.

While policies are necessarily formulated from a top-down perspective, it is pertinent to acknowledge that consumers' experiences can vary significantly according to context. This underscores the need to also develop a bottom-up understanding of the primary challenges encountered by consumers, even when there are existing incentives and schemes in place. Gaining a deeper understanding of these challenges can be instrumental in adjusting and complementing existing initiatives to expedite the expansion of decentralised renewable energy, specifically rooftop solar.

In this context, this study aims to assess the current challenges and opportunities for scaling up renewable energy adoption in India based on the perceptions and feedback from existing power consumers. These are gauged through a large-scale ground survey conducted in multiple states across the country.

Objectives and Methodology

This study aims to develop a bottom-up understanding of the bottlenecks that impede the success of decentralised solutions to renewable energy adoption, particularly rooftop solar. It also seeks to identify a roadmap for directing policy support for overcoming these barriers.

The primary objective is to understand the key technical, informational, policy, and regulatory bottlenecks for adopting rooftop solar as perceived by different electricity consumer groups. Moreover, the study tries to assess how perceptions regarding renewable energy influence behavioural decisions related to adoption of rooftop solar, particularly for residential consumers. This will help link the ground realities and existing narratives that guide the current policy discourse around renewable energy.

The study combines information from existing literature, policy documents, secondary data, and stakeholder consultations, with findings from an extensive primary survey.

The following are the objectives of the study:

- Assess current patterns of electricity consumption in terms of both intensity and timing to identify the user groups most suitable for the adoption of decentralised renewable energy solutions.
- Evaluate the degree of rooftop solar adoption across various consumer segments and document the characteristics and experiences of these users.
- Assess perceptions of renewable energy in terms of reliability and cost effectiveness and identify preferred modes of adopting renewable energy.

- Identify key factors that influence the willingness to pay for decentralised renewable energy solutions.
- Identify key policy and technical barriers to renewable energy adoption as perceived by consumers.

The larger aim is to combine the learnings from the above objectives to develop a policy roadmap to improve the adoption of decentralised renewable energy in India.

Study Approach

The key contribution of this study is a large-scale survey across six Indian states covering more than 7,500 respondents—both commercial and industrial power consumers, and residential. To provide context to the survey findings and identify solutions to policy and regulatory bottlenecks, the survey is complemented by a thorough analysis of the national- and state-level policies and regulations governing renewable energy adoption, with a particular focus on rooftop solar.

Selection of Consumer Groups for the Survey

The survey gathered insights from two main consumer groups: residential, and commercial and industrial (together referred to as C&I consumers). However, due to limited resources, the authors had to work with a fixed sample size. Consequently, an initial analysis of the current status of renewable energy adoption was conducted for both consumer groups. This analysis was followed by a stakeholder consultation process to determine which consumer segments should be prioritised, considering where the survey inputs could have the most substantial policy implications.

Rooftop solar (RTS) is the main segment where consumer participation is critical for increased adoption. The reasons for the adoption of RTS, as well as the policy structures and incentives, differ substantially between the residential and C&I consumer groups, as well as across states.

The residential segment has seen slow historical growth in rooftop solar, with annual capacity additions stagnant at around 200 MW up till 2020. Since then, growth has been promising, with annual installed capacity crossing 700 MW in FY22 and FY23.[4] The possible reasons for the increased uptake could include a streamlining of the processes for availing incentives, easier regulations for net metering, increased financing options, and growing awareness among consumers. Although there has

been a notable expansion in the residential sector, the majority of rooftop solar capacity—approximately 9 GW out of the total installed capacity of 11.6 GW—is still dominated by C&I consumers.[5]

The consumer groups also differ substantially in terms of policy and regulatory support. The residential segment has received substantial policy support—for example, Phase II of the Grid Connected Rooftop Solar Programme contains a comprehensive action plan including central subsidies for the adoption of rooftop solar in the residential segment. The process for applying for these subsidies has also been streamlined through the creation of the National Solar Rooftop Portal, where residential consumers can apply directly for the subsidies. State policies around RTS also have a specific focus on the residential segment. Moreover, there has recently been attention on improving consumer awareness. The Ministry of New and Renewable Energy launched a pan-India campaign in 2023 to improve awareness, particularly in Tier-2 and Tier-3 cities.

In contrast, the growth in the C&I segment has occurred without targeted support. Neither the National Rooftop Solar Policy nor state policies provide specific incentives for these consumers. The financial stability of utilities also relies heavily on the revenue generated from the C&I segment. This is because C&I consumers pay higher tariffs, which in turn subsidise the residential and agricultural consumers. As a result, distribution companies (DISCOMs) lack clear incentives to encourage adoption in this segment as it is perceived to reduce their revenue. This manifests itself in regulatory and procedural complications for C&I consumers looking to adopt solar. In some cases, this also leads to financial penalties for C&I consumers planning to shift away from grid electricity, who are made to pay a cross-subsidy surcharge in some states ranging from 15 percent in Gujarat to 52 percent in West Bengal.[6]

As a result, solar installations in the C&I segment are driven by larger firms with large-scale solar installations. In the industrial segment in particular, a majority of the solar rooftop installations are carried out by medium and large enterprises. This leaves out most of the Micro, Small, and Medium Enterprises (MSMEs), which account for the largest share of industrial output and employment in India. The potential for MSMEs to adopt solar holds great promise, with estimates suggesting that the demand for rooftop solar in this segment alone could add between 16 and 18 GW of rooftop solar capacity.[7]

Furthermore, much of the research initiatives have also focused on the residential segment.[8,9,10] However, there is a dearth of information regarding the key perceived challenges for consumers in the C&I sector,[11] particularly for MSMEs, whose specific challenges are often neglected in the policy discourse or the positions put forward by industry bodies. While some surveys have been undertaken to understand challenges from the C&I segment, these have been small in scale, limited in geographies, and focused on specific clusters. There was a need for a systematic survey of C&I consumers with a sample size that could provide a representative assessment of the needs of this sector. Thus, while the survey in this study was carried out for both segments, greater weightage has been given to the C&I segment, leading to a unique large-scale survey of these consumers covering a total sample size of more than 6,500 respondents across six states. The sample size for the residential consumers was smaller but also substantial, covering more than 1,000 respondents.

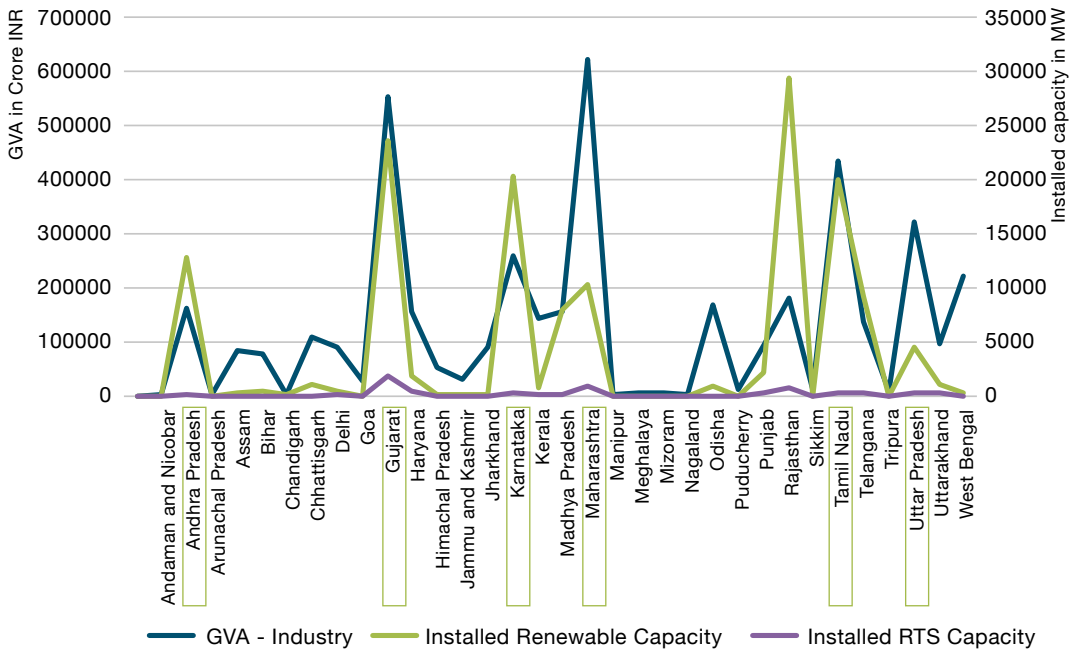
State Selection

To ensure a more representative sample, the authors adopted a focused approach instead of attempting to cover small samples in each of the states. A smaller set of states was carefully selected, allowing for substantial and representative samples within each of the six that were chosen.

The selection was driven by the aim of capturing the diverse range of circumstances related to renewable energy adoption in India. In applying specific criteria, these states were not only found to be relevant to the survey but also reflected the circumstances faced by other states not included in the study but experiencing similar challenges.

Given the focus on renewable energy and the C&I segment, three specific criteria were chosen to assess the suitability of states: i) the industry's contribution to State Gross Value Added (GVA) and number of factories; ii) installed renewable capacity; and iii) installed rooftop solar capacity. Based on this analysis, states were grouped in two categories: i) leaders in rooftop solar and have a substantial industrial sector; and ii) have a substantial industrial sector but are performing poorly in adding rooftop solar capacity. The following six states were selected for the final survey (see Figure 1):

Figure 1: Industrial Activity and Renewable Energy Progress, by State



Sources: Ministry of New and Renewable Energy[12] *and Ministry of Statistics and Programme Implementation*[13]

a. Leaders in rooftop solar and substantial industrial sector

Gujarat: Ranked second in terms of gross value added from industries and total number of factories. Ranked second in terms of installed renewable capacity and the highest for installed rooftop solar capacity. The state is amongst the first movers in implementing a solar policy, with its first iteration launched in 2009.

Maharashtra: First in terms of GVA from industries and third highest in number of factories. Second highest in terms of installed solar rooftop capacity. The state launched a solar policy in 2017, with the latest iteration of the policies launched in 2022 raising the ambitions for solar energy adoption.

Karnataka: Recognised as a leader in renewables with the state launching the first iteration of its solar policy in 2011. Ranks third in overall installed capacity and fifth in rooftop solar. However, its industrial development is slightly lower than the other two states in this segment, ranking fifth in gross value added from industries and seventh in the number of factories.

b. Substantial industrial sector but poor performance in rooftop solar

Andhra Pradesh: Fourth in terms of number of factories but very poor performance with solar, particularly rooftop—14th in terms of installed rooftop solar capacity.

Tamil Nadu: First in terms of the number of factories and ranks third in gross value added from industry. However, it ranks fourth in installed capacity and shows poor performance in rooftop solar, ranked sixth. Tamil Nadu has been a leader in wind power, but the growth of solar has been relatively limited.

Uttar Pradesh: Fourth in GVA added from industries and fifth in the number of factories but poor performance in adding renewable capacity, ninth in overall renewable installed capacity, and eighth for rooftop solar.

Survey Design

The survey instrument was designed based on a review of the existing literature, validated from inputs from developers, regulators, financial institutions, and other research organisations to ensure policy relevance. The most important themes addressed in the survey are explained in the following paragraphs:

- **Current power consumption patterns:** The decision to adopt rooftop solar or other decentralised renewable energy (DRE) technologies depends on the consumer's perception regarding the ability of the new technology to perform the same functions as grid-based electricity while providing other potential cost benefits.[14,15] Given that rooftop solar differs from traditional grid electricity in that generation is only possible during the sunlight hours, the ability for RTS to meet consumers' power requirements will depend on current consumption patterns both in terms of intensity and timing.

  Technical Barriers: As with all new technologies, RTS adoption continues to be hampered by uncertainty regarding the appropriate technical specifications, reliability of the system, and maintenance issues. The survey aimed to capture perception of consumers related to the technical aspects of RTS adoption. This also included an assessment of the awareness around different stages of RTS adoption and the perceived challenges with each stage.

The survey aims to identify current electricity consumption patterns among various industrial and residential consumer groups. It seeks to establish connections between these patterns and the existing capabilities of rooftop solar technologies. The authors also tried to capture the reliability of current electricity sources since RTS could also act as a solution for unreliable power supply for certain consumers given the right conditions.[16]

- **Technical Barriers:** The adoption of rooftop solar involves several stages, including the identification of the right technological specifications and solution providers, resolving space requirements, installation, and maintenance, among others. However, uncertainty at any of these stages can influence the decision to adopt RTS. Thus, the survey aimed to assess the current awareness levels around technical capabilities of RTS as well as knowledge regarding the different stages of adopting RTS. This will help identify the bottlenecks in the process of installing RTS that continue to hamper adoption levels.

- **Financial and Financing Barriers:** The key barrier to RTS adoption remains the high upfront cost of installation. Typically, discussions surrounding this issue emphasise the long-term savings due to the much lower operational costs associated with RTS. This is because once installed, the marginal cost of utilising electricity from renewable sources is close to zero. However, the decision to purchase RTS is influenced by whether the long-term cost savings are effectively integrated into the decision-making process. To gauge the perception of cost-related factors, the survey included questions aimed at better understanding whether the argument for cost reductions from RTS is gaining traction in practice.

  Furthermore, developers offer both OPEX/RESCO (operational expenditure) and CAPEX (capital expenditure) based business models. Each of these models carries distinct risks and advantages for both developers and consumers. The objective of the survey was to assess the perception of these diverse business models and examine how they influence consumers' decisions to invest in RTS. The survey also assessed which financing options were being utilised by existing RTS users. For non-users, the survey assessed

the willingness to pay under different business models and their preferences for different financing options.

- **Policy and Regulatory Barriers:** Rooftop Solar is subject to various policy incentives and regulatory procedures. These also vary greatly by type of consumer and location. The survey aimed to assess the awareness and perceived ease of availing the schemes and navigating procedures. For existing RTS users, the survey aimed to understand how much the current policies and regulations influenced their decision to adopt this technology and where they faced the greatest challenges. Non-RTS users were also asked about the areas of support required for them to contemplate adopting these new technologies.

- **Environmental Preferences:** The survey also assessed the perception of consumers regarding the importance of renewable energy and the switch away from fossil fuel-based electricity. This is particularly relevant for the residential segment, where the perceived benefits of rooftop solar are often correlated with environmental concern, risk-taking appetite, and other subjective norms.[17] The survey instrument included carefully designed questions to assess the relationship between perceived benefits and reasons for adopting RTS.

Policy Environment for Rooftop Solar in India

Status of Rooftop Solar

As of May 2023, the total installed capacity for rooftop solar stood at around 9.4 GW, with the residential sector seeing faster growth.[18] In the first quarter of 2023, the majority of the added rooftop solar installations, accounting for 58 percent, were attributed to the residential sector. The commercial sector contributed 14 percent of the installations, while the industrial sector accounted for 28 percent of the installations.

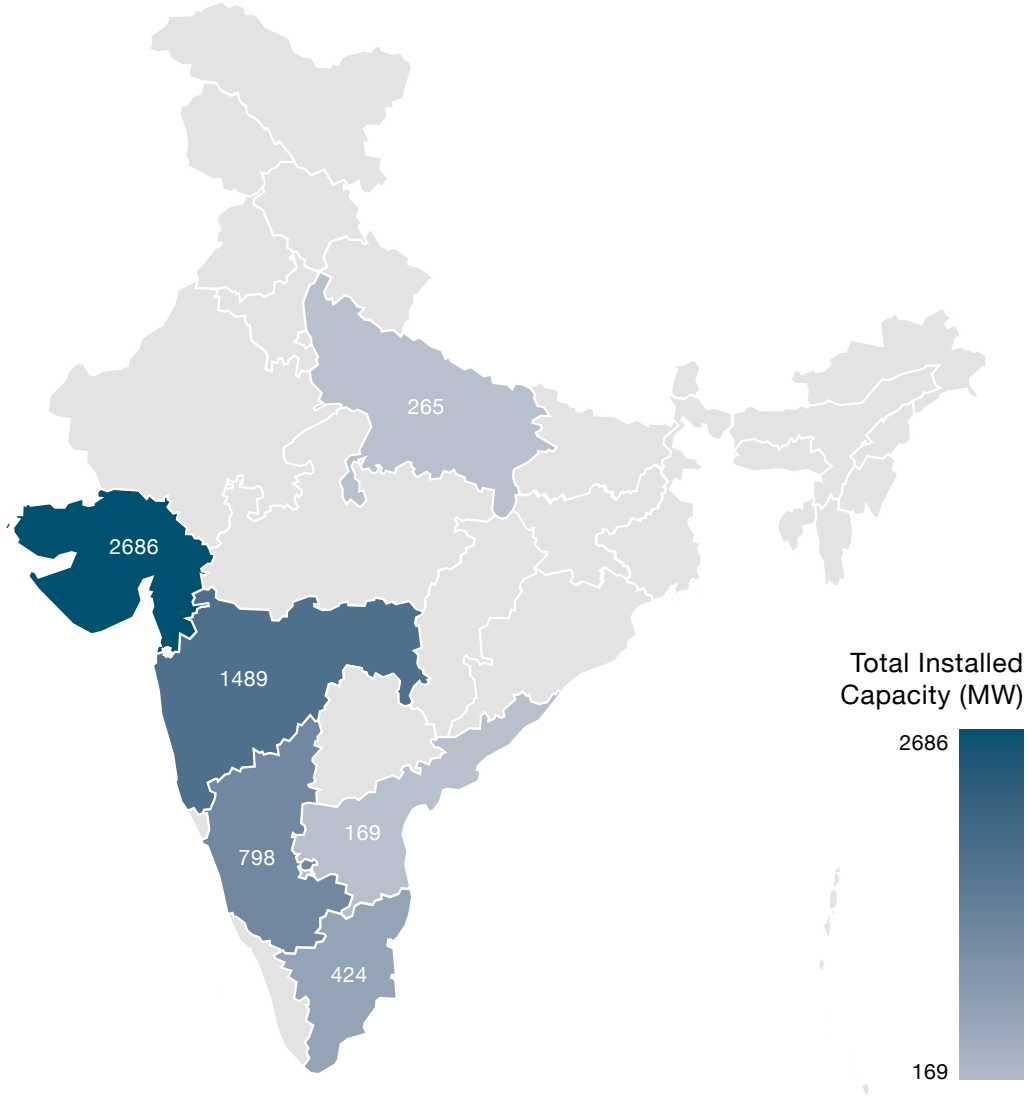
The C&I segment accounted for approximately three-quarters of the total solar rooftop installations in 2022. As of December 2022, total installations in the C&I segment reached 9,044 MW. Notably, Gujarat, Rajasthan, Karnataka, Maharashtra, and Tamil Nadu collectively represent 50 percent of the total C&I rooftop solar installations in India.[19] Consequentially, this segment accounts for approximately 50 percent of electricity consumption and pays higher tariffs than residential users. From FY2012 to FY2021, electricity consumption across the C&I segment rose by a CAGR of 4.30 percent, while the grid tariffs increased at the rate of 2 percent.[20] Furthermore, the MSMEs account for 25 percent of the overall electricity consumption of the industrial sector.[21]

On the other hand, as mentioned in the previous section, the growth rate of the residential rooftop solar segment has remained consistently slow, at approximately 200 MW installations per year until FY2020, with an estimated installation rate of only 0.9 percent among independent urban households. However, there has been a recent surge in residential RTS installations, with annual installed capacity reaching around 700 MW in March 2023.

Of the states included in the survey, Gujarat and Maharashtra are the leading states in RTS adoption. The total installed RTS capacity in Gujarat stands at 2,868 MW and

in Maharashtra at 1,489 MW[22] (see Figure 2). State-level policies and incentives in these states have helped rooftop installations grow significantly.

Figure 2: Overview of Rooftop Solar Progress in the Study States



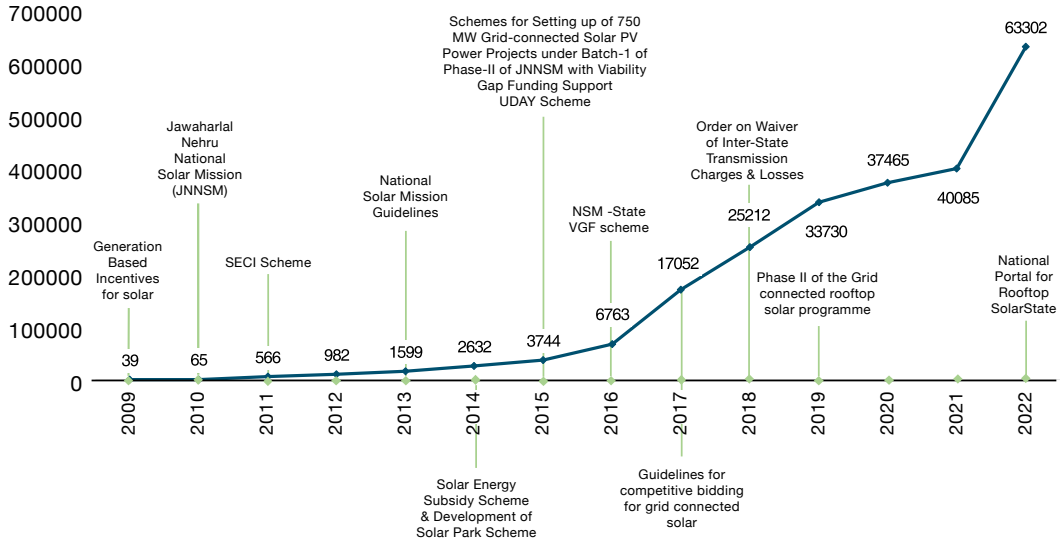
Source: MNRE (2023)

Central Government Policies

Acknowledging the role of solar in India's energy future, the Indian government introduced the Jawaharlal Nehru National Solar Mission in 2010. In 2015, a target of achieving 175 GW of renewable energy by 2022 was announced, including 100 GW of solar energy.[23]

To accelerate rooftop solar growth, the central and state governments have announced a number of measures in recent years. In 2015, the MNRE launched the Grid Connected Rooftop and Small Solar Power Plants Programme (Phase I) to incentivise solar rooftop installations. The programme offered subsidies of up to 30 percent of the benchmark cost for general category states and up to 70 percent for special category states. These subsidies supported installations in residential, institutional, and social sectors. The Rooftop Solar Program Phase-II was launched in 2019 with a target of installing 4,000 MW capacity in the residential sector by providing Central Financial Assistance to the DISCOMs. The programme provides a total central support of US$1.4 billion.[24] Figure 3 captures India's solar journey since 2009. The clear targets and policies set in 2015 for rooftop solar have had a significant impact on India's cumulative solar installed capacity. Solar installations have grown at a rapid pace from 2015 onwards.

Figure 3: Timeline of Solar Energy Initiatives in India: Solar Policies vs. Installed Capacity (MW)



Source: Authors' own, using data from MNRE dashboard, GOI

Sub-National Policy Landscape

There is substantial state-level support for solar energy which works in consonance with the Central policies (see Table 1). All six states included in the survey have their own renewable energy policies, as well as separate policies for solar energy.

Of the six states, Uttar Pradesh has the highest target of 6,000 MW for rooftop solar, out of which 4,500 is for the residential segment.[25] However, the state's total solar rooftop installed capacity is around 265 MW as of May 2023.[26] Gujarat leads the six states in terms of its installed capacity and is the only state to have reached around 90 percent of its target 3,200 MW RTS. Andhra Pradesh's solar policy targets a minimum total solar power capacity addition of 5,000 MW by 2023 but does not include a separate target for rooftop solar. The total RTS installations in the state stood at around 169 MW as of May 2023—the lowest of the six states. In addition to having a specific solar policy, Tamil Nadu is the only state to have a Solar Energy Action Plan in addition to its solar policy.[27] The state has managed to achieve 30 percent of its RTS target, and the total RTS installations in the state stood at 424 MW as of May 2023.

Table 1: Policy Support for Rooftop Solar, by State

State Policies Overview	Uttar Pradesh	Maharashtra	Gujarat	Tamil Nadu	Karnataka	Andhra Pradesh
Standalone State Renewable Energy Policy	✓	✓	✓	✓	✓	✓
Standalone State Solar Policy	✓	✓	✓	✓	✓	✓
Official renewable energy target	✓	✓	✓	✓	✓	✓
Official Solar Targets (MW)	22000	12390	8020*	9000	-	5000
Official Rooftop Solar Targets (MW)	4500 – Residential 150 0- C&I	2000	3200	1500	1000	-
Installed Capacity (MW) (May 2023)	265	1489	2686	424	798	169
Renewable energy/Solar energy action plan to attain the target	X	X	X	✓	X	X

Source: Authors' own, based on state solar and renewable energy policies

Net Metering Regulations

Transitioning to RTS is challenging due to high initial costs that hinder investment. To incentivise adoption, consumers need attractive long-term returns. The ability of RTS users to sell back excess renewable energy to the grid thus becomes crucial. Net metering is a crucial enabler of maximising financial returns from the RTS system. Under this arrangement, the electricity generated by the consumer is subtracted from the total electricity consumed during a specific period. The adjustments can occur on a monthly, half-yearly, or annual basis. In contrast, in a gross metering system, the consumer is eligible for compensation at a predetermined feed-in tariff for every unit of solar energy generated and exported to the grid. This is measured by a unidirectional 'gross meter' that accounts for the total exported energy. On the other hand, the consumer is required to pay the electricity distribution company the retail supply tariff for the electricity consumed from the grid.

There are substantial differences around specific net metering regulations across states (see Table 2). All the six states selected for the survey have active net metering regulations; UP, Gujarat, Tamil Nadu, and Andhra Pradesh have active gross metering regulations as well.[28] Various conditionalities related to net metering also influence the ability of consumers to maximise benefits from these systems:

a. Limitations on installation size

A state's net metering regulation enforces restrictions on the size of rooftop solar systems that can be installed within their jurisdiction. These limitations primarily impact the C&I sector, which typically has substantial energy demands and the resources to implement larger rooftop solar installations. The allowed limit is below 1 MW for most states except Uttar Pradesh and Karnataka which both allow connectivity up to 2 MW. Restrictions on system size hinder the economic feasibility of RTS, as a 1 MW system can only generate 1.3–1.4 million units of electricity annually, potentially falling short of the high energy needs of large commercial and industrial consumers.

b. Transformer capacity restrictions

Every state has regulations that impose a constraint on the overall capacity of rooftop solar installations connected to a single distribution transformer in each area. Typically, this restriction is a fraction of the capacity of the distribution transformer. The purpose of this limitation is to control the widespread adoption of rooftop solar systems within a state. When the cumulative capacity remains low, it directly impacts the ability of prosumers to install rooftop solar, thereby significantly influencing the desirability for solar investment particularly for consumers with high power demand. Furthermore, this restriction serves as an indicator of the quality of the existing infrastructure, as a higher limit is typically associated with better infrastructure. The varying limitations on the transformer capacity across states are noteworthy. For instance, Andhra Pradesh allows deploying RTS capacity up to 100 percent of the transformer capacity, while in Uttar Pradesh only 25 percent of the capacity is allowed.

c. Export of electricity for consumption

For grid integration of the generated electricity, the net metering regulations also cap the export of electricity for consumption. As per this limitation, states like Tamil Nadu mandate that the capacity exported should not exceed the capacity consumed (100 percent). In these states, there will be no compensation for the surplus power.

d. Billing period

The payment settlement time denotes the payback time taken by the DISCOMs for the surplus power received by them from the prosumer. The settlement time is a critical factor in determining the overall cost benefits. The shorter the settlement time, the shorter the payback period, resulting in a stronger business case. In most states, the billing period is monthly and the compensation period is set to yearly, again with differences across states.

Table 2: Net-Metering Regulations, by State

State	Gross/Net	Consumer Segment Applicable	Technical Configurations		Grid Integration Specifications		
			Range Allowed	Limitations on transformer capacity	Export of electricity allowed when compared to consumption	Billing period for settlement	Compensation period for surplus
Uttar Pradesh	Both	Agricultural or metered Residential/ Domestic category under LMV-5 and LMV-1	1 kW–2 MW	25%	Above 100%	Monthly	Yearly
Maharashtra	Net	All Consumers	1kW - 70% of DT (Distribution Transformer)	40%	Above 100%	Monthly	Yearly
Gujarat	Both	Industrial, Commercial and Other Consumers	1 kW–1 MW	65%	Above 100%	Monthly	Yearly
Tamil Nadu	Net	Consumers under the LT category	Above 1kW	90%	90%	Bi-Monthly	Yearly
Karnataka	Both	Only for Low Tension (LT) residential consumers	1 kW–2 MW	80%	Above 100%	Monthly	Monthly
Andhra Pradesh	Both	All consumers	1 kW–1 MW	80% for LT 100% for HT	Above 100%	Monthly	Quarterly

Source: CEEW (2019)

Financial Incentives for RTS

Given the high upfront cost of rooftop solar installations, direct financial incentives have been a key instrument utilised by the Central and State governments to encourage greater adoption. However, the incentives differ substantially by type of consumer. This section highlights some of those differences.

a. Residential consumers

Central government: Under the Central Financial Assistance (CFA) initiative, the Ministry of New & Renewable Energy (MNRE) provides subsidies to consumers, accessible through State Nodal Agencies. These subsidies are exclusively applicable to the residential sector, including individual homes and large-scale apartments, while excluding commercial and industrial sectors. Additionally, the solar subsidy is solely accessible for grid-connected solar systems, without the inclusion of battery systems. The structure and components of the subsidy scheme are provided in Table 3. MNRE also facilitates the provision of low-interest loans for RTS adoption. This is enabled through an online platform called SPIN, which assists in determining the total area available for rooftop solar panels, the capacity of solar panels that can be installed, and the associated budget constraints.[29]

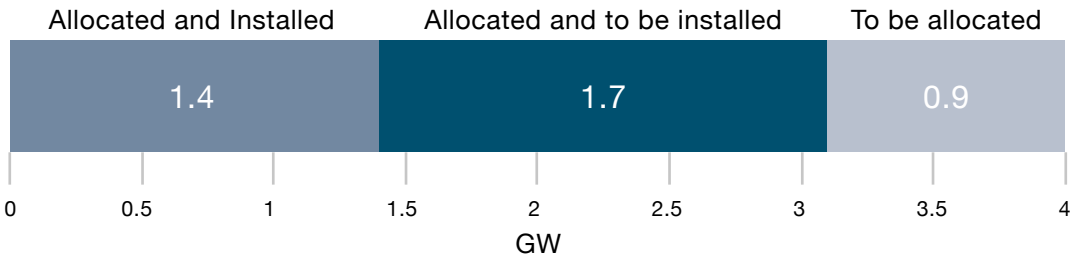
Table 3: Central Subsidies for Rooftop Solar

System Capacity (kW)	Subsidy (%)	Subsidy (INR)
1 kW to 3 kW	40 %	INR 14,588/- per kW
4 kW- 10 kW	20%	INR 14,588/- per kW for the first 3 kW and thereafter INT 7,294/- per kW
More than 10kW	Fixed Rate	INR 94,822/- fixed

Source: Ministry of New and Renewable Energy, Grid Connected Rooftop Solar Division

The Ministry of New and Renewable Energy (MNRE) launched Phase II of the Grid Connected Solar Rooftop Program to help reach the target of 40 GW of rooftop solar capacity by 2022. However, as of 30 July 2022, MNRE has allocated 3.1 GW of residential rooftop solar capacity out of the targeted 4 GW. Out of the allocated capacity, a cumulative total of 1.4 GW has been successfully installed under the program (see Figure 4).

Figure 4: Status of Grid-Connected Rooftop Solar and Small Solar Power Plants Programme (Phase 2) for Residential Segment (as of July 2022)



Source: IEEFA[30]

State government: Gujarat and Maharashtra account for about 45 percent of the overall installed RTS capacity in India.[31] One of the primary reasons for the growth of RTS in these states is the subsidies provided by their state governments. Gujarat's Surya Urja Rooftop Yojana provides 40 percent and 20 percent state subsidies for RTS installations up to 3 KW and 10 KW, respectively.[32] Gujarat's new solar policy also allows RTS users to rent their premises to a third party for electricity generation, which is likely to encourage more solar installations. The Maharashtra government also provides a subsidy of 20 percent to 40 percent to the residential segment for RTS installations and a 20 percent subsidy on project costs for 1 KW to 500 KW to the housing societies and resident welfare associations.[33]

b. Electricity utilities (DISCOMs)

MNRE has implemented a performance-based financial incentive program for DISCOMs under Phase II of the Grid Connected Rooftop Solar Program. This programme aims to promote the adoption of rooftop solar systems by providing incentives based on the DISCOMs' progress in deploying such systems. Incentives include annual payments of 5 percent of benchmark RTS costs for capacity additions exceeding 10 percent of DISCOMs' previous year's total RTS capacity,

and 10 percent of benchmark costs for achieving over 15 percent of the installed capacity. DISCOMs are also eligible for service charges of up to 3 percent of the central financial assistance for residential solar rooftop projects.[34]

c. Commercial and industrial consumers

There are no subsidies provided at the central or state level for the installation of RTS for C&I consumers. Neither the National Rooftop Solar Policy nor the state policies provide specific incentives for this segment. However, there are certain tax benefits available. For instance, if an RTS system is installed by C&I entities and remains operational for at least 180 days, they qualify to receive a depreciation benefit of between 40 percent and 20 percent. This regulation was implemented in 2017. However, if the RTS system operates for less than 180 days in a year, the owners of the solar photovoltaic (SPV) plants can claim a 30 percent depreciation, which is half of the full-year allowance.

DISCOM Performance and RTS Adoption

Electricity utilities play a key role in advancing renewable energy installations acting as the key link between synergising grid electricity with increasing decentralised generation capacity. However, as more consumers shift away from grid electricity, DISCOMs lose out on sources of revenue. In particular, the shift towards rooftop solar in the C&I segment can have a potentially substantial impact on a DISCOM's financial health as these are the most profitable consumers that pay the highest tariffs to DISCOMs.

Indeed, the DISCOMs in India are already suffering huge losses, especially after the COVID-19 pandemic. The fear of revenue loss discourages them from supporting the acceleration of RTS deployment. The Performance of State Power Utilities 2019-20 report by the Power Finance Corporation Limited during FY 2019–20 suggests that the ACS-ARR gap has reached 95 paise per unit, AT&C losses have approached 22.32 percent, and the aggregated losses of DISCOMs were reported at INR 44,160 crores.[35]

The relatively low penetration of RTS across the Indian landscape has not substantially affected DISCOM finances. However, when the respective states will start achieving their RTS targets, DISCOMs are likely to bear the brunt. Therefore, for DISCOMs to lead the change by playing a key role in rapid RTS deployment, they

must be of sound financial health. The six selected states are analysed on the following three indicators to assess the financial health of their DISCOMs (see Table 4).

a. Debt-to-equity ratio

The debt-to-equity ratio evaluates the financial leverage of DISCOMs. A lower ratio signifies reduced risk for investors, making it appealing. This, in turn, fosters favourable investment conditions and contributes to enhancing the overall performance of DISCOMs. Across the six states included in the survey, DISCOMs in Andhra Pradesh and Tamil Nadu have a negative debt-equity ratio of -1.4 and -1.8, respectively (see Table 4), which reflects their weak financial profile as compared to other states.

b. Aggregate technical & commercial losses

Aggregate technical & commercial (AT&C) losses provide a realistic picture of the efficiency of DISCOMs in recovering the cost of electricity supply; a higher loss signifies lower revenue per unit of supply. DISCOMs in each state should target to reduce AT&C losses through improving billing efficiency and collection efficiency. Amongst the six states, Uttar Pradesh has the highest AT&C losses, at approximately 26 percent, closely followed by Andhra Pradesh and Maharashtra, with AT&C losses of around 19 percent each. Since RTS systems are perceived to have low interconnection costs, they can save a significant amount of energy that is lost while being transmitted and supplied through the grid. This can be the primary motivation for states with high AT&C losses to shift to renewable technologies like RTS. These high AT&C losses and the inability of power tariffs to recover supply costs have contributed significantly to the increase in DISCOM losses over the years. Therefore, any endeavour to extensively implement rooftop solar solutions must consider this market reality and establish incentives for DISCOMs to back such initiatives.

c. Complexity in tariff structure and cross-subsidisation

The high grid tariffs for the C&I segment may result in inefficiencies, as the C&I sector is required to pay high tariffs to subsidise electricity consumption in the agriculture and domestic sectors. This current tariff design structure for the C&I segment is the biggest incentive, making self-generation for C&I more cost-effective. However, it also poses a significant disadvantage for DISCOMs, as they rely heavily on the revenue generated from the C&I segment. This creates a sub-optimal situation, where DISCOMs lack clear incentives to encourage adoption

in the C&I segment as it may reduce their revenue. Amongst the six states included in the survey, the cross-subsidy value ranges from INR 0.3/kWh (for Maharashtra) INR 3.6/kWh (for Tamil Nadu). These comparatively high cross-subsidisation rates in Tamil Nadu, Uttar Pradesh, and Andhra Pradesh result in high C&I grid tariffs in these states.

Table 4: DISCOM Financial Indicators

Indicators	Uttar Pradesh	Maharashtra	Gujarat	Tamil Nadu	Karnataka	Andhra Pradesh
Debt-to-Equity Ratio (2022)	3.2	1.4	0.1	-1.8	7.1	-1.4
Aggregate Technical & Commercial Losses (2023)	26.47	18.68	10.99	12.24	12.64	18.93
Cross Subsidisation (INR/kWh) (2022)	3.2	0.3	1.1	3.6	1	3

Source: NITI Aayog (2022)[36]

Survey Insights: Commercial and Industrial Consumers

Sample Frame

The survey sample was designed to capture a representative cross-section of the commercial and industrial sectors based on the population of industries in the six states as per the Annual Survey of Industries (ASI). Previous surveys have focused on targeted analysis within specific clusters in the industrial segment, whereas this sample includes a broader set of the total population and captures both MSMEs and larger industries.

The authors utilised the sample frame of the ASI (2019) as the population for this survey. The ASI is the primary source of industrial statistics in India and is conducted by the Industrial Statistics Wing of the Central Statistics Office. It covers the entire country and includes the following:

i. All factories registered under Sections 2m(i) and 2m(ii) of the Factories Act, 1948.
ii. Units involved in specific services, motor vehicle repair, and a selection of other consumer durables like watches.
iii. All *bidi* and cigar manufacturing establishments registered under the Bidi and Cigar Workers (Condition of Employment) Act, 1966.

Therefore, the ASI sample frame provides the most comprehensive data source for capturing the scale and composition of the industrial sector in India and was deemed appropriate for conducting a representative survey within this segment.

However, it must be noted that the ASI does not include the unorganised sector. The unorganised sector is instead addressed through surveys conducted by the National Sample Survey Office (NSSO). The unavailability of a definitive sample

frame derived from existing NSSO data hindered its inclusion in this survey. Moreover, certain commercial electricity consumers may not be included if their services fall outside the purview of ASI coverage.

Pilot Survey

Before the final survey, an extensive pilot was undertaken to gain a preliminary understanding of renewable energy adoption within our sample frame. Given the limited literature on RE adoption in this segment, the pilot also allowed us to test the framing of the questions and the validity of responses. It also helped address certain logistical challenges associated with such a survey. For instance, our approach of aiming for a sample that represented the overall population rather than targeting specific industrial clusters or regions posed a challenge in identifying, locating, and reaching out to industrial units spread across extensive geographic areas. Furthermore, since the last ASI, conducted before the COVID-19 pandemic, several units have ceased to exist or been relocated, necessitating the need for backup samples for each respondent. The pilot played a crucial role in resolving many of these problems.

The pilot survey was carried out across all six states, covering 1,898 respondents. The sample was stratified according to State and National Industrial Classification (NIC) codes, with the distribution in the pilot following the distribution in the ASI sample frame.

Overall, around 3 percent of the sample (55 respondents) were found to be utilising rooftop solar. However, there were major state-wise differences in the adoption. Gujarat had the highest prevalence of RTS, with 11 percent of the sample reporting usage, followed by Maharashtra (2 percent) and Karnataka (1 percent). None of the respondents in Tamil Nadu and Andhra Pradesh reported using RTS. The pilot also captured the reliance on backup sources and found that the majority of the sample reported reliability issues with grid electricity, with 36 percent of the sample reporting utilisation of Diesel Generators (DG sets) as a backup source of energy. Further information collected in relation to energy consumption patterns, perception of RE, and policy barriers helped inform the framing of questions in the final survey.

The relationship between RTS usage and other variables was also tested statistically through a LOGIT regression analysis using data from the pilot survey. Geographical location was found to be an important determinant of RTS adoption, with a

statistically higher probability of adoption estimated for respondents in Gujarat and Maharashtra. No statistically significant relationship was found between the intensity of electricity consumption and RTS usage. However, the probability of RTS adoption increased with the size of the industrial unit, although this relationship was not linear, suggesting that the probability of adoption was the highest for medium to large firms but did not necessarily translate into greater probabilities for the largest firms.

Final Survey Sample

The final survey included 4,542 respondents across six states. These states account for 33 percent of the total industrial units included in the ASI sample frame, and the survey sample accounts for 4 percent of the total industrial units in the six states, which were further stratified based on industry size and type of industries following the ASI distribution. The selected states also account for around 47 percent of the total electricity consumption in the commercial and industrial sectors in India.[37]

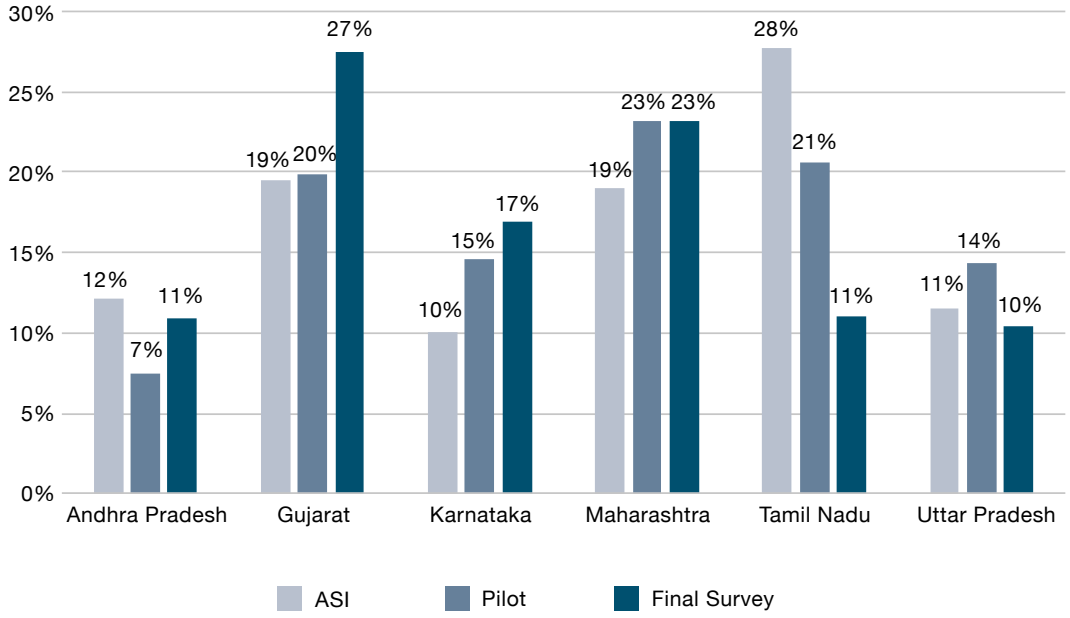
Since one of the objectives was to survey both current and potential RTS users, the distribution of the sample across states was informed by the pilot survey (Figure 5). Due to the higher prevalence of RTS usage in Gujarat, the final sample intentionally included a larger sample from Gujarat compared to the distribution from ASI, whereas a smaller sample was selected from Tamil Nadu. However, the sample was also influenced by logistical considerations; in instances where accessing units in certain states was challenging, they were reallocated to other states.

The sample also covered industries across 25 two-digit NIC codes out of the total 38 NIC codes included in the ASI sample frame. These 25 codes cover more than 90 percent of the total sample frame. The analysis was carried out at the two-digit NIC level to allow for the clear identification of industry-level results, which could also be fairly representative.

In terms of industry size, the sample was designed to be representative of the overall ASI sample frame. As the ASI does not offer industry classification based on revenue, the sample distribution by industry was determined by considering the number of employees. However, our survey also collected data on revenue, which allowed us to classify industries based on their annual revenue.

The majority of our sample comprised small and medium enterprises, with 32 percent reporting an annual revenue below INR 5 crore and 85 percent reporting an annual revenue below INR 50 crore. Larger enterprises accounted for approximately 2 percent of the sample. Therefore, our sample offers a useful comparison of the perceptions of the MSMEs compared to larger industries.

Figure 5: Distribution of the Survey Sample for C&I Consumers, by State



Electricity Consumption Patterns

Electricity consumption patterns were assessed based on the size and type of industries. A substantial difference was reported in the average expenditure on electricity across different industry sizes. Large industries[a] reported an average monthly electricity expenditure of around INR 84 lakh, whereas the smallest enterprises reported an average of INR 0.84 lakh. Overall, electricity costs were found to comprise an average of 3 percent of the total operational costs. However, despite the large differences in absolute expenditure, the share of electricity costs

[a] The classification of industries considered in the study are as follows: (a) Large industries: annual revenue above INR 250 crores, (b) Medium industries: annual revenue between INR 50 crores and 250 crores, and (c) small and micro industries: annual revenue below INR 50 crores.

in total operational costs was found to be higher for smaller industrial units (Figure 6). This suggests that, while electricity is a crucial input in the production process in industrial units of all sizes, its importance may be comparatively greater in smaller units. This finding could have important implications for advancing renewable energy in smaller industries as a means of reducing operational costs.

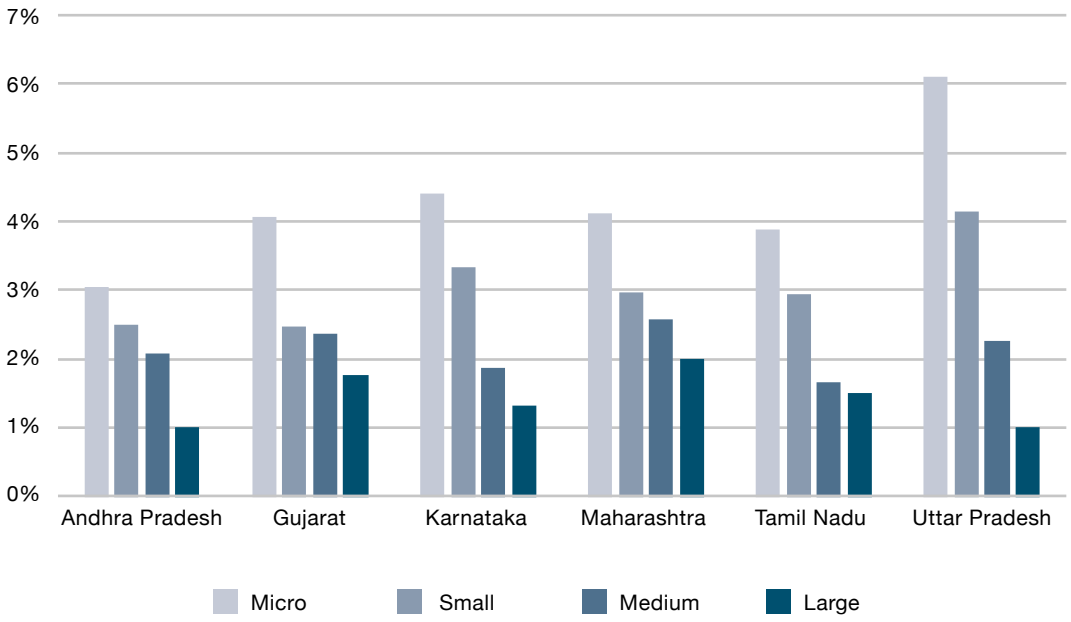
It must be noted that the share of electricity costs reported in our survey might be lower than in other studies. A recent analysis by the Bureau of Energy Efficiency of 35 industrial SME clusters found that energy costs could account for anywhere between 10 and 40 percent of total production costs.[38] However, across the clusters, electricity was not the major form of energy used in the production process; instead, biomass-based energy was found to make up a large part of the energy requirements, along with coal/coke and diesel. Another study of MSME clusters found that, for certain industries, such as machine manufacturing, cold chain warehousing, and automobile products, the share of electricity in total energy consumption could be as high as 80 percent.[39] In our sample, the highest share of electricity in total costs was found to be in machinery manufacturing.

Given that C&I consumers in India pay higher electricity tariffs to cross-subsidise other consumers, a major argument for RTS adoption has been the opportunities for industries to reduce production costs by reducing electricity costs. This means that, from a financial point of view, industries with the highest share of electricity costs in total production might be the best suited to adopt solar.

Based on the proportion of electricity consumption across NIC codes and a comparison with industries with existing adoption of RTS in our sample, a few industries stand out as potential frontrunners for RTS adoption. These industries include machinery and equipment manufacturing, leather and related industries, apparel manufacturing, beverages, and pharmaceuticals.

Among these industries, machinery manufacturing, leather, and pharmaceuticals have been identified as frontrunner segments in other studies.[40,41] However, certain industries such as warehousing and plastics do not emerge in our analysis due to the criteria of existing adoption and potential savings from reduced electricity costs but have been highlighted in other studies.

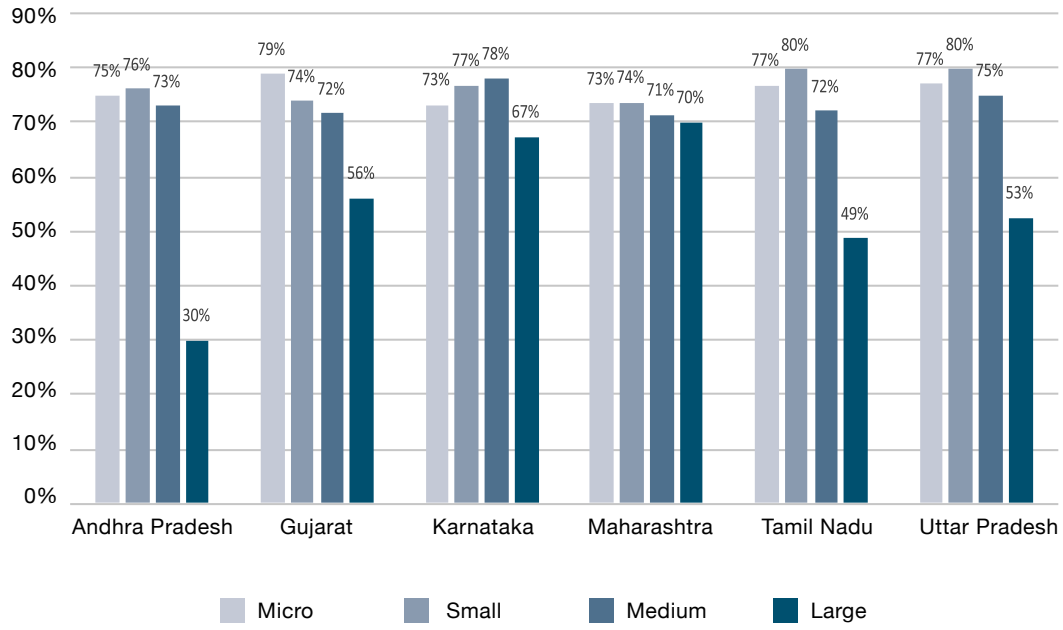
Figure 6: Electricity Expenditure as a Percentage of Total Cost



The timing and duration of electricity usage is another important variable to consider when assessing the potential for adopting renewable energy. Across the sample, respondents reported an average daily electricity requirement of 11 hours. The duration of electricity use was found to increase with the size of the industrial units, with the largest industry size category reporting an average daily requirement of 17 hours.

Electricity demand was also reported to be strongly concentrated in the daylight hours. Across the sample, 75 percent of the electricity was reported to be utilised on average between 9 am and 4 pm. This percentage was higher for smaller industries, where the average utilisation in daylight hours was much higher than the sample average (Figure 7). This has positive implications for solar energy adoption in the MSME segment, particularly since battery storage remains expensive and unaffordable for most consumers.

Figure 7: Proportion of Electricity Demand During Daylight Hours

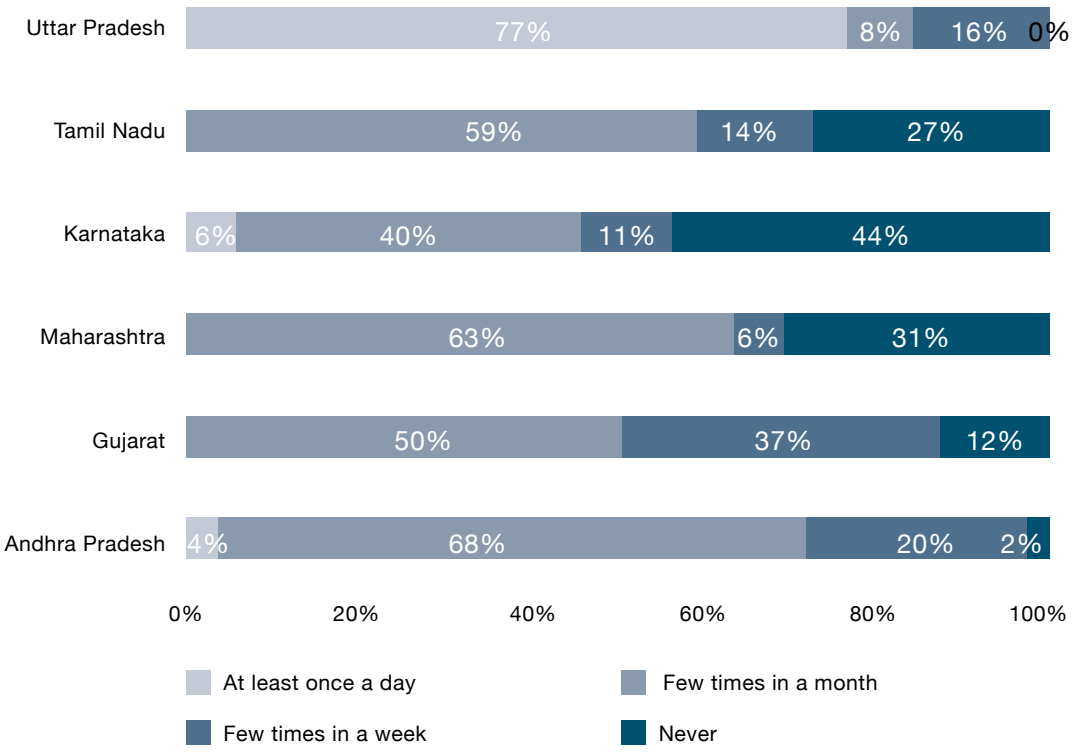


Reliability of Grid-Based Electricity and Backup Sources

The reliability of and satisfaction with current sources of electricity can also be useful indicators of the potential opportunities for shifting to renewable energy. The survey contained several questions related to the reliability of grid-based electricity and current dependence on backup sources.

The majority of the sample reported a high prevalence of power cuts that continue to affect business operations, with only around 20 percent of the sample reporting never experiencing power cuts. There were also substantial differences by state (Figure 8). In Uttar Pradesh, 76 percent of the respondents reported that power cuts curtailed operations daily. Andhra Pradesh and Gujarat also reported a very high prevalence of power cuts but with less frequency. Given that predictable and steady availability is critical for business operations, particularly for firms involved in manufacturing processes, the continuous availability of power remains a critical challenge.

Figure 8: Prevalence of Power Cuts for C&I Consumers, by State



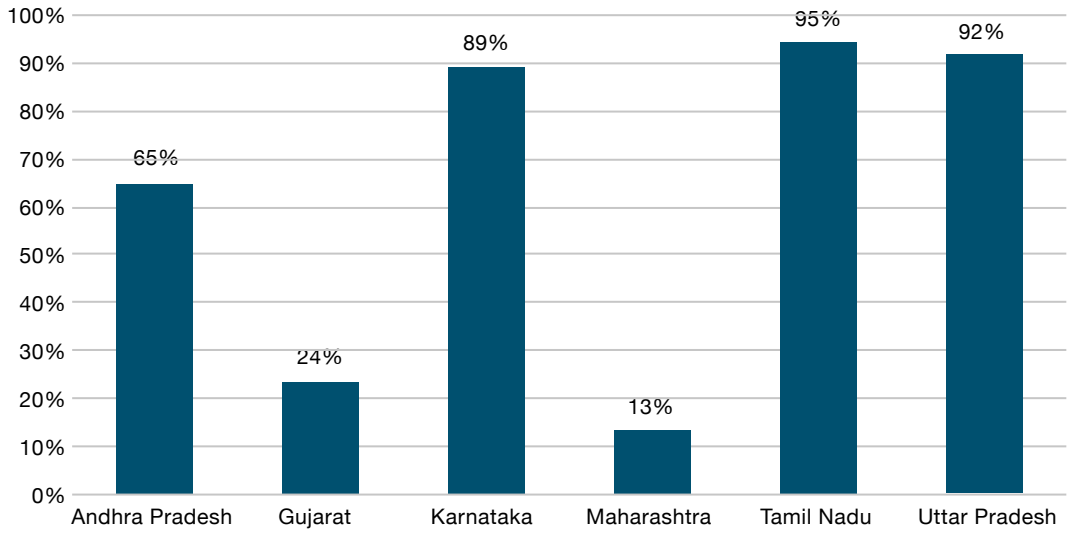
The lack of reliability associated with grid electricity is also borne out in the prevalence of DG set usage for backup power (Figure 9). Around half the sample (47 percent) reported using a DG set for backup power. There was also substantial state-wise variation, with 90 percent or more of the respondents in Tamil Nadu, Karnataka, and Uttar Pradesh reporting the use of DG sets. Gujarat and Maharashtra had the least prevalence, with less than 25 percent of respondents utilising DG sets. The heavy dependence on DG sets can also be ascertained from the fact that 83 percent of DG set users in the sample utilise large industrial sets above 100 KVA, suggesting that these DG sets play an important role in overall business operations in the absence of grid electricity.

There is also substantial expenditure on DG sets. The average price of a DG set across the sample was around INR 15 lakh, but for larger industries this was as high as INR 75 lakh. The operational costs on these sets were also substantial, with average annual expenditure ranging from INR 1.8 lakh in Karnataka to INR 3.54 lakh in Uttar Pradesh. Thus, DG sets continue to play a critical role in

the business operations of C&I consumers. This leads to an increase in the cost of electricity due to both the need to spend on purchasing these machines and the higher cost of diesel-based power generation compared to grid-based electricity. The costs are also more variable, given the fluctuation in diesel prices. Additionally, DG sets are highly polluting, leading to increased carbon emissions and local air pollution. Reducing dependence on DG sets through greater adoption of decentralised renewable energy solutions could provide substantial benefits for both consumers as well as society.

However, the timing of DG-set usage will be an important factor in determining the potential of replacing them with rooftop solar solutions. The survey responses were found to be encouraging for renewable energy usage; more than 75 percent of DG set users reported utilising the backup sources during daylight hours. This trend was observed across states and industry types, with the lowest usage in daylight hours occurring in industries in Gujarat (63 percent) and Maharashtra (58 percent). The morning usage of the DG set was also higher in smaller industries, with MSMEs showing the highest utilisation during the day. This hints at the substantial scope for positioning RTS as an alternative backup source to DG sets.

Figure 9: Proportion of the Sample Utilising DG Sets, by State

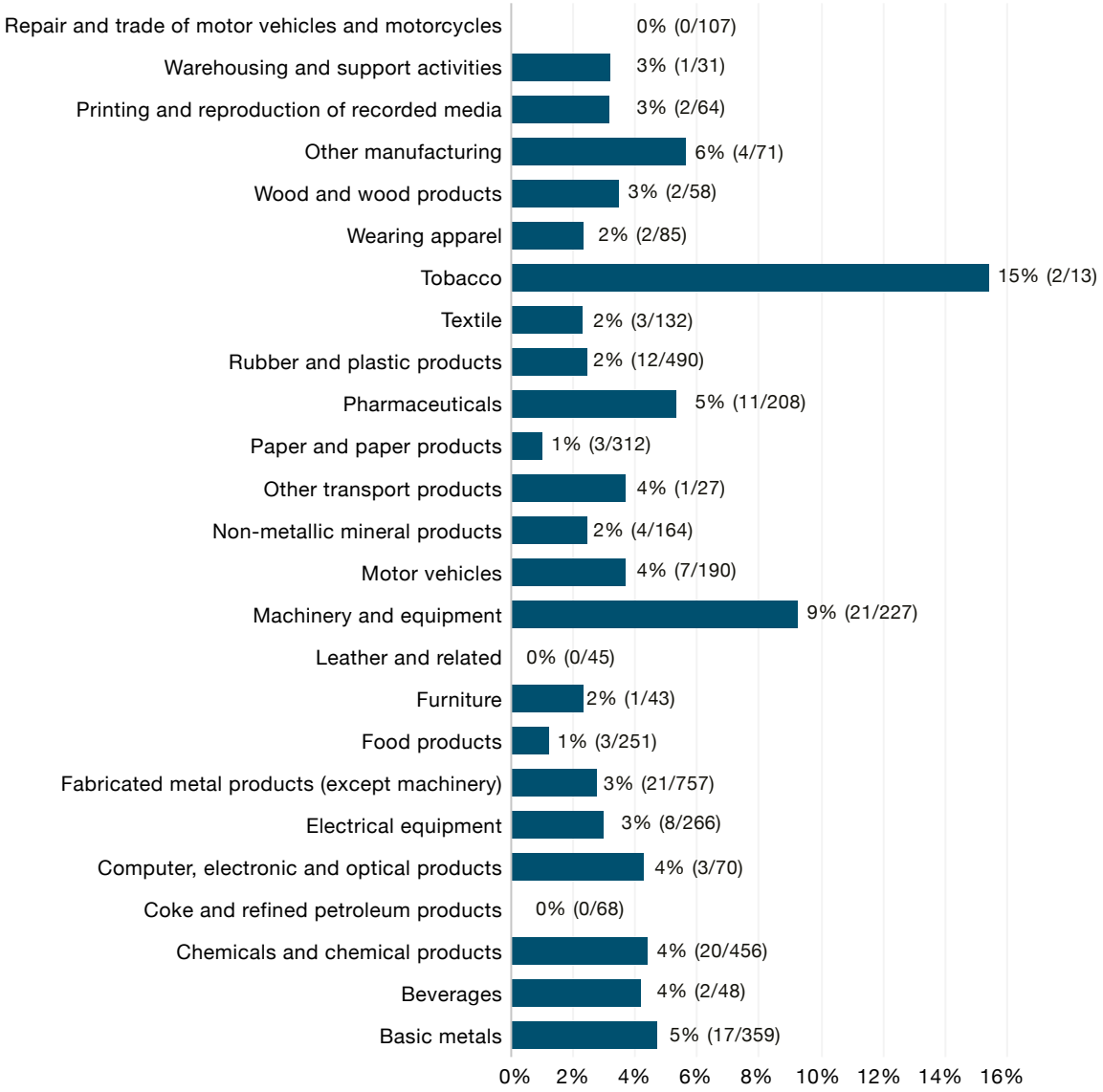


Rooftop Solar Adoption Levels

In the overall sample, 150 respondents (3 percent) reported utilising rooftop solar. Similar to the pilot, prevalence was highest in Gujarat, with 9 percent of respondents in the state reporting RTS usage, followed by Uttar Pradesh (3 percent), Maharashtra (2 percent), and Andhra Pradesh (1 percent). None of the respondents in Tamil Nadu and Karnataka reported utilising RTS. There was also a substantial difference in RTS adoption across industry sizes; the highest RTS adoption was found in medium-sized enterprises with annual revenue of INR 50 crores to 250 crores, with 7 percent of the respondents in this category reporting RTS usage. The lowest adoption was seen in industries with revenue below INR 5 crores, even though this segment accounted for a large part of the sample. Perhaps surprisingly, only 3 percent of the respondents in the larger industries, with annual turnover above INR 250 crores, reported utilising RTS.

There was also substantial difference across industries in terms of RTS adoption (Figure 10). Some of the industries which stand out in terms of high RTS prevalence include machinery and equipment manufacturing, which includes general purpose and specialised equipment, which does not include motor vehicle manufacturing, pharmaceuticals, basic metals, chemicals, chemical products, and fabricated metal products.

Figure 10: Rooftop Solar Adoption, by Industry



**Values in brackets indicate absolute numbers.*

Insights from Existing RTS Users

The survey had a separate set of questions for RTS users to understand the characteristics of the RTS system, gather feedback on the system, business model, and policy support (Table 5). Most RTS users were medium- to long-term users of solar, with the average age of the RTS system ranging from 4.38 years in Uttar Pradesh to 6.5 years in Andhra Pradesh. This indicates that the recent emphasis on renewable energy and the growing awareness of RTS has not significantly propelled adoption in this particular segment. Moreover, it may also imply that the COVID-19 pandemic has had an impact on the uptake of RTS, as most users had installed their systems before the pandemic.

Around 88 percent of RTS users had systems connected to the grid. Only 30 percent of the users had some form of battery storage, with these users concentrated in the larger industries. This highlights the current high costs of battery storage and implies that the utilisation of the RTS system is restricted to daylight hours, when solar generation is feasible. There is a pressing need to prioritise the development of battery-storage solutions, particularly for smaller industrial units, to address this limitation.

Respondents were instructed to rate the RTS system on a scale of 1 to 5, where 1 indicated complete dissatisfaction and 5 indicated utmost satisfaction. They were also asked to rate the performance of the RTS system on multiple criteria (Table 5), as follows:

- **Reliability:** This criterion aimed to evaluate the extent to which the RTS system effectively fulfilled the consumer's expectations of reliable electricity supply. There was a substantial difference across industry sizes; while small and medium enterprises expressed high levels of satisfaction with the system's reliability, large industries reported significantly lower scores. When considering this information, alongside electricity consumption data, it becomes apparent that, as the total electricity requirement and duration of electricity usage increase, the perceived reliability of RTS to meet electricity diminishes. Consequently, without advancements in storage technologies, adopting RTS will prove to be more challenging for industries with greater electricity demands.

- **Cost savings:** Respondents were asked to rate their electricity cost savings after installing the RTS systems. Across the sample, cost savings from RTS did not receive very high scores, with an average score of 3.4 out of 5 across all RTS users, indicating only medium satisfaction with cost reductions. Larger industries in particular reported very low satisfaction with cost reductions after installing the RTS system. This has broader implications for the narrative that higher upfront costs are covered by the long-term cost savings from RTS, leading to a net cost benefit.[42] Our findings indicate that the cost savings from RTS are not perceived as excessively high, even among long-term users who have been utilising RTS for over three years, which is close to the expected cost breakeven point.

- **Ease of maintenance and after-sales service:** Operation and maintenance remain a challenge even after the installation of RTS. This includes regular tasks which help maintain the efficiency of the solar panels that require work from the adopters of RTS. However, the major maintenance and repair tasks for these systems are usually carried out by the developers either on their own or through contracted operation and maintenance companies, particularly in the case of operating cost-based adoption models (OPEX or RESCO model). Our results indicate that, across industry sizes, there is not very high satisfaction when it comes to ease of maintaining the system. This was particularly true for larger industries where the installed capacity of the RTS systems is also higher. Moreover, there was quite a lot of dissatisfaction with customer service from the suppliers of RTS. This indicates that several kinks need to be resolved to ensure that, even after purchase, the experience with RTS can suit the needs of consumers. This also reflects the fact that there has been a reported shortage in manpower in the renewable energy segment, which leads to poor customer service and long maintenance times owing to the lack of technicians who are able to service geographically disparate customers.

Table 5: Average Performance Scores for RTS from Existing Users*

	< INR 5 crores	INR 5-50 crores	INR 50-250 crores	> INR 250 crore
Reliability	4.4	4.4	4.2	3
Cost Reduction	3.9	3.3	3.7	1.5
Ease of Maintenance	3.9	3.2	3.4	1.5
Customer Service	2.7	3.7	3.74	4

**The rating scale is from 1 to 5, with 1 signifying completely unsatisfied to 5 signifying extremely satisfied.*

Insights from Potential RTS Users

The survey had a separate set of questionnaires for respondents who are not using rooftop solar at present.

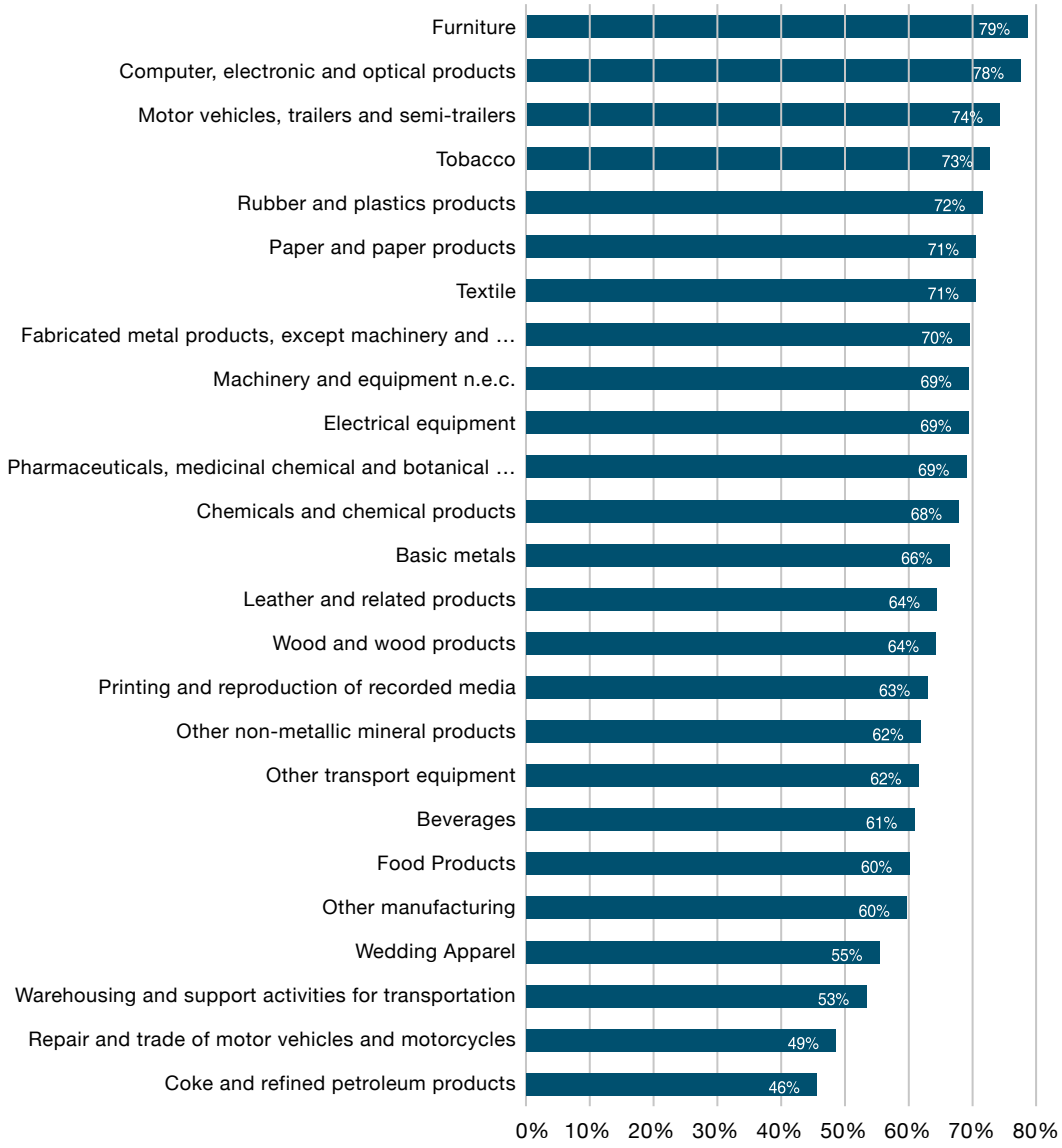
a. Receptiveness towards renewable energy

The survey sought to assess the receptiveness of potential adopters towards renewable energy by trying to gauge their willingness to shift to renewables, the preferred mode of shift, and their willingness to pay.

- Overall, there was a substantial interest across states and industrial segments to adopt renewable energy as a part of their electricity consumption patterns. More than 65 percent of the respondents across states and industries expressed a strong willingness to shift to renewable energy. Industries that reported the highest willingness to shift were manufactures of furniture, computer electronic and optical products, motor vehicles, trailers and semi-trailers, paper products, rubber and plastic products, fabricated metal products, and textiles. These industries can be targeted for specific RTS adoption programmes (Figure 11).

The respondents were also asked about their preferred mode to shift to renewables. Respondents in most states (five out of six) reported a preference to purchase renewable electricity from the grid, closely followed by setting up a rooftop solar system. Across all industrial segments, respondents were evenly split between those who preferred purchasing renewable electricity from the grid and those who favoured installing rooftop solar systems, with approximately 60 percent of the respondents opting for either choice.

Figure 11: Percentage of Industries Willing to Shift to Renewable Energy



b. Awareness of rooftop solar

The widespread diffusion of newer technologies is contingent upon their commercial and social acceptance which, in turn, hinges upon the extent of public awareness about their technical and regulatory requirements. In the absence of adequate information, the willingness to shift to a novel technological intervention like rooftop solar can be limited.

Therefore, one of the objectives of conducting the survey was to gauge the awareness levels related to various aspects of rooftop solar, primarily regarding the following:

Processes and procedures for installing RTS

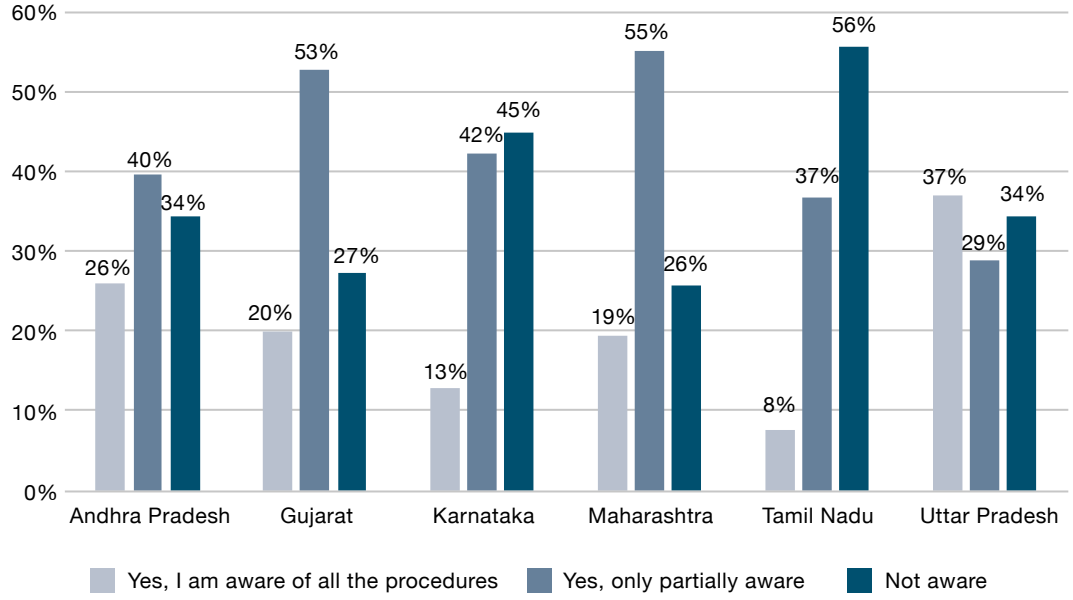
Encouragingly, around 65 percent of respondents from the selected states were either fully or partially aware of the processes and procedures for installing a rooftop system (Figure 12). In the industrial segments surveyed, the awareness was comparatively low amongst the large industries, with 48 percent reporting that they did not know about the procedures for installing RTS.

Policy support

The respondents were also asked if they were aware of any policy support available to support RTS adoption in their respective states. Across the six states, more than 40 percent of the respondents were not aware of any policy support for RTS, except the state of Uttar Pradesh, where 43 percent of the respondents were aware of RTS policies. Similarly, across industrial segments, more than 50 percent of the respondents across both MSMEs and large industries were unaware of any policy support available for RTS.

This lack of awareness and information asymmetry across selected states and industries regarding the crucial technical and regulatory aspects of RTS can significantly hinder its adoption. Hence, providing information and raising awareness across consumer and industrial segments is essential.

Figure 12: Awareness Regarding the Process and Procedures for RTS, by State



c. Willingness to pay and preferred business models for rooftop solar

Respondents were also asked about their willingness to pay for RTS and their preferred business model. Due to the substantial investment needed to advance RTS in India, it is essential to develop and promote innovative business models accompanied by effective fiscal and financial incentives. The respondents were given a choice between the two most prominent RTS business models in the country—capital expenditure (CAPEX) and operational expenditure (OPEX, also known as RESCO).

Overview of RTS Business Models

In India, the most prevalent approach for implementing RTS involves the use of the CAPEX model. Under this model, consumers take ownership of the system, finance its installation, and utilise the generated energy, thereby assuming the risks associated with the system's operation, management, and maintenance. Consumers typically secure funding for the project through banks, and they have the option to apply for capital subsidies offered by the Central Financial Assistance (CFA) as well as additional subsidies provided by state governments. However, it is important to note that this model places the highest level of risk on the owner.

The OPEX model, alternatively referred to as the RESCO model or third-party financing model, is distinguished by the involvement of the energy company RESCO, which procures the necessary capital for RTS projects and takes ownership of the entirety of its associated risks. Within this model, developers engage in contractual

arrangements with proprietors of rooftops. The inherent technical and financial characteristics of these models are provided in Table 6.

Table 6: Features of CAPEX and OPEX Business Models

Characteristics Features of the Models			
Dimension	**Key Features**	**CAPEX Model**	**OPEX Model**
Technical	Ownership structure	Consumer	RESCO
	Operation, management, and maintenance	Consumer	RESCO
	Installation	Consumer	RESCO
	Arrangement with utility	Consumer	RESCO
	Installation risk	High	Low
	Risks related to the import/ export of energy	High	Low
	Risks related to technical constraints such as system sizing and limit on transformer	High	Low
Financial	Capital investment	Mostly by Consumer	Through banks
	O&M expenses	Consumer	RESCO
	Cost to consumer	Capital and O&M expenses	Negligible investment by the consumer
	Tariff setting	As per regulations	A tripartite agreement between RESCO, consumer, and utility
	Payback period	4-6 years	N/A*
	Liquidity risks	High	Low
	Payment risks	High	Low
	Payback period risks	High	Low
	Project management risks	High	Low

Source: Sarangi and Hesary (2021)[3]

**Payback period under the OPEX model is not applicable as the consumer only has to pay for the energy generated. All capital expenses and risks are entirely borne by the developer, who also has to provide for the O&M services.*

Survey Insights

According to our survey, across all industry segments, over 60 percent of the respondents were not willing to pay anything extra for RTS. However, even if they are willing, they would prefer making an outright purchase rather than involving an external provider (Figure 13), as respondents considered it to be cheaper in the long run. About 90 percent of the RTS installed in the country follows the CAPEX model (also known as the outright purchase model) (Figure 14).

While considering emerging business models, it is important to assist consumers in becoming more aware of the different business modalities. These findings also make a clear and strong case for raising awareness regarding different available business models, their cost effectiveness, their advantages and disadvantages, and varying technical, operational, regulatory, and financial features to enable consumers to make an informed decision.

Figure 13: Preferred Payment Model for RTS

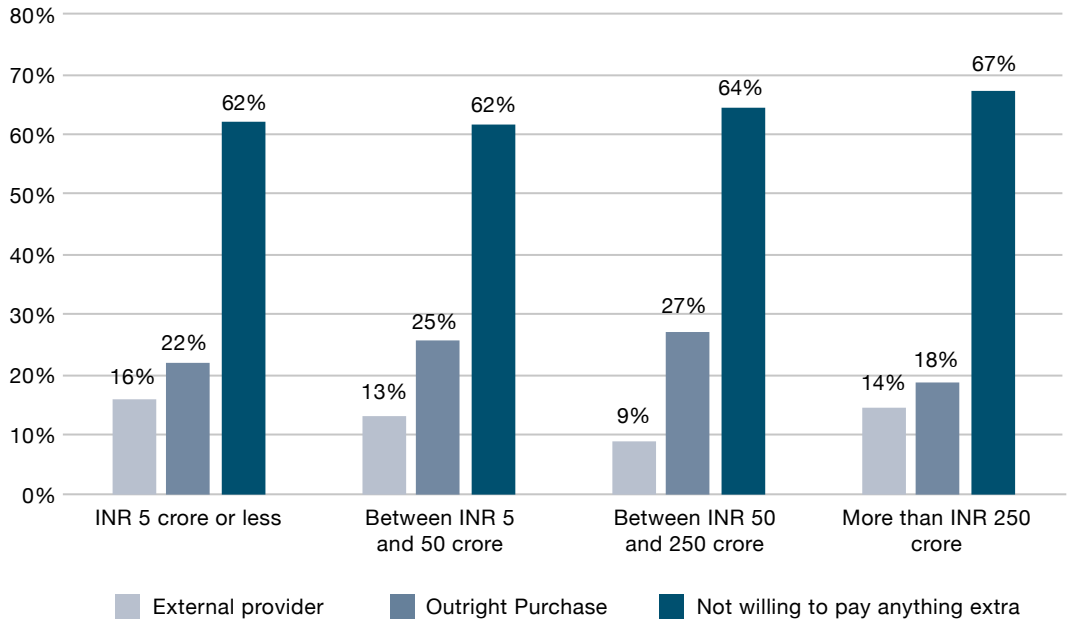
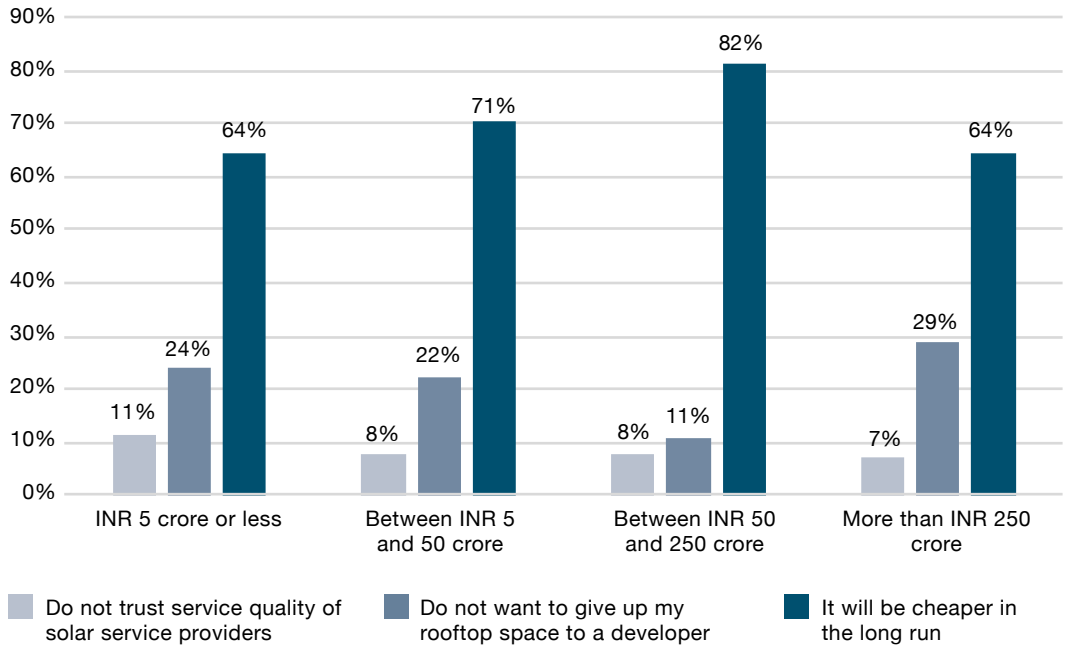


Figure 14: Reasons for Choosing an Outright Purchase Model



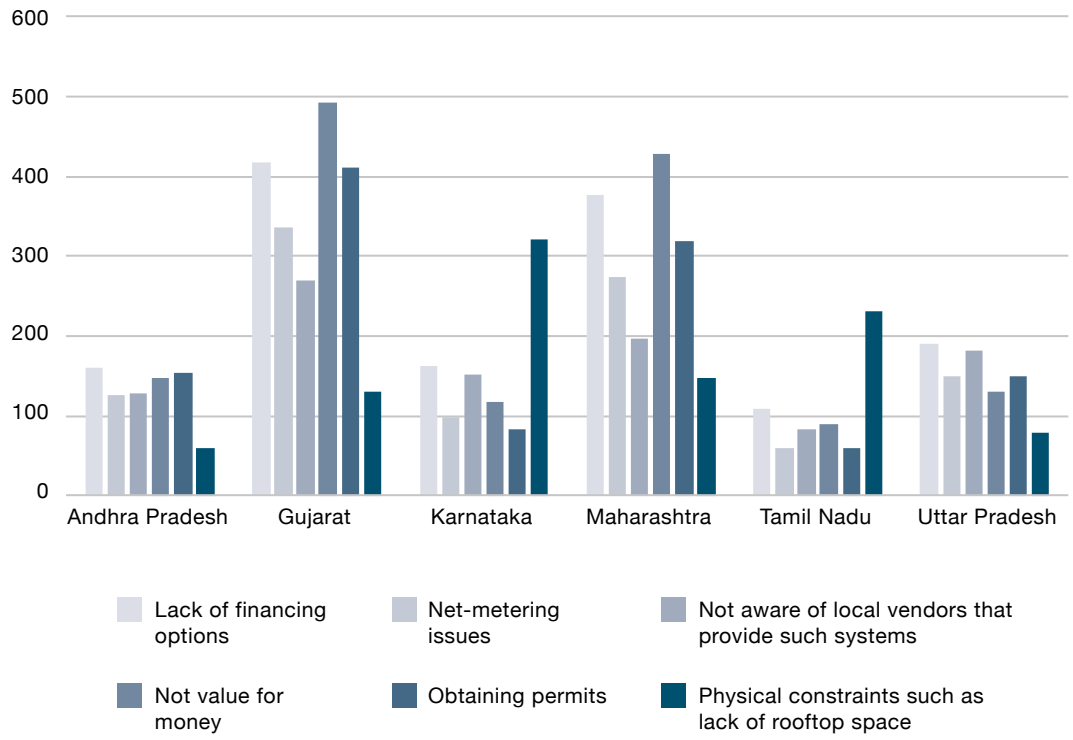
d. Identified bottlenecks for RTS adoption

The survey also tried to gauge major barriers to the adoption of rooftop solar, as perceived by potential users of RTS:

- According to our survey, respondents from Andhra Pradesh and Uttar Pradesh considered the lack of financing options to be a primary challenge. Meanwhile, respondents in Gujarat and Maharashtra perceived RTS as not being a value-for-money option. Additionally, in Karnataka and Tamil Nadu, physical constraints in terms of lack of space to install the system components were the most prevalent challenge to the adoption of RTS (Figure 15).
- For MSMEs, the lack of financing options acts as a major barrier to the adoption of RTS. MSMEs already struggle with severe access to finance issues due to the lack of a credit-worthy profile.[44] This segment requires targeted support and financial incentives.
- In larger industries, physical constraints also emerged as a major barrier. The literature also suggests that these industries are often located in very congested industrial estates.

- The survey also tried to gauge the problems associated with the installation of rooftop solar and the stage of installation that poses the biggest challenge. For respondents in Andhra Pradesh, Uttar Pradesh, and Maharashtra, the biggest challenge is associated with the stage of installing the system, whereas for respondents in Tamil Nadu and Karnataka, it is the operation and maintenance of RTS. For all industry segments, the biggest challenge is at the stage of installing the system, followed by the operation and maintenance of the RTS.

Figure 15: Key Bottlenecks in Adopting Rooftop Solar as Identified by Respondents



Perception of Government Support

Both solar and non-solar survey respondents were asked about their preferred interventions and areas of additional support which could aid their decision for purchasing rooftop solar:

- It was observed that, across states and industrial segments, the most preferred interventions to accelerate the adoption of rooftop solar was the subsidisation of purchase cost, closely followed by the provision of low-interest loans. As seen in the previous sections, the lack of financing options is the biggest barrier to RTS adoption across states. Currently, unlike in the residential segment, there are no central or state subsidies available for commercial and industrial segments. Additionally, MSMEs struggle with severe issues in terms of access to finance due to the absence of a credit-worthy profile. Commercial banks are often hesitant to offer loans for RTS projects due to their small size and fragmented nature.

- There was also a demand for improved net metering regulations from all six states. The rules and regulations required for the net metering framework vary from state to state. Even within a state, the process of net metering is not standardised. Respective state nodal agencies also impose additional clearances that are not specified in the state's solar policy. Additionally, there are no defined timelines for the granting of approvals by the various agencies involved, leading to delays and losses.

These findings indicate that there is an urgent need for introducing incentives and policies, as well as procedures to accelerate RTS adoption in the C&I segment.

Survey Insights: Residential Consumers

The survey for residential consumers was spread across Tier-1 and Tier-2 cities in the six selected states. The final sample included 1,019 respondents spread over 40 cities.

a. Electricity consumption patterns

The sample included households across various income groups and electricity consumption patterns. The total electricity consumption was positively correlated with the average household income. The average monthly electricity expenditure across the sample was INR 1,400, with the highest average expenditure on electricity reported by respondents in Karnataka (INR 1,829) and Tamil Nadu (INR 1,539).

The reliability of grid electricity was a significant concern for residential consumers. Out of the total respondents, approximately 730 individuals (71 percent) reported experiencing power cuts of varying frequencies. This problem was most pronounced in UP, where 42 percent of respondents experienced daily power cuts; and Maharashtra, where 13 percent reported daily power cuts. Other states experienced comparatively lower frequencies of power cuts, with Gujarat performing the best, with 60 percent of respondents indicating no issues with power cuts. The duration of power cuts was also an area of concern, with an average duration of eight hours reported for power cuts in a month across states, with Andhra Pradesh reporting the highest, with 11 hours of power cuts a month on average.

Despite the widespread occurrence of power cuts, residential consumers displayed lower utilisation of backup power sources compared to C&I consumers. Only 7 respondents from the total sample reported utilising a backup source of power such as inverters or DG sets. The usage of backup sources was also limited to higher-income households. These results suggest that a substantial portion of residential

consumers continue to suffer from a lack of electricity for extended periods and do not opt for backup sources because of a lack of affordability.

b. Renewable energy adoption

Renewable energy usage was very low among the residential consumers covered in the survey. Only five respondents (<1 percent) reported using rooftop solar, and none of them reported utilising any other kind of solar appliances. This reflects the nascent potential of solar in the residential segment and highlights the immediate need to accelerate adoption in this segment to realise the vast potential of rooftop solar in India.

Among the respondents who used RTS, four out of five reported a significant reduction in their electricity costs following the installation. They also reported that one of their key reasons for adopting RTS was as a solution to power cut issues. This highlights that rooftop solar power has the potential to significantly benefit residential consumers, offering not only a reduction in electricity expenses but also a solution to the challenges posed by unreliable electricity, especially during the summer months, when limited access to power can have various health implications.

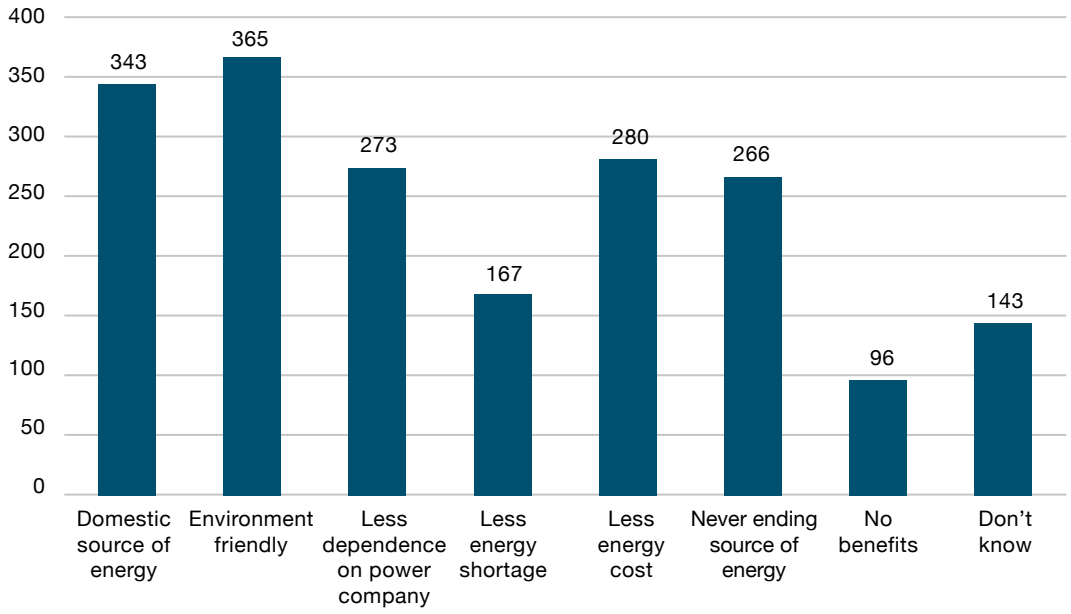
The CAPEX-based purchase model was also the most prevalent adoption model among RTS users, with four out of five users choosing to utilise this model, with an average expenditure of INR 3.5 lakh. Respondents cited a lack of awareness regarding vendors offering the OPEX model as the primary reason for their preference for the CAPEX model. This highlights the need for improving accessibility to OPEX-based models for smaller, residential consumers. In addition, respondents expressed concerns about the limited availability of loans for RTS purchases; many reported being offered interest rates above 10 percent, as these were general personal loans rather than specialised loans for RTS. This poses a significant barrier, especially for lower-income consumers and could explain why the survey results showed a higher adoption rate of the CAPEX model among higher-income households.

c. Perception of green energy

The perception of renewable energy and the environmental preferences of households are important indicators of rooftop solar adoption. Furthermore, gaining insights into people's perceptions regarding renewable energy can provide valuable insights into how policies related to green growth and renewable energy are perceived by citizens of the country.

Encouragingly, 64 percent of respondents stated that the need for transitioning to renewable energy should be an urgent policy priority. This widespread support signals a broad-based endorsement of the ongoing renewable energy transition in India. However, 67 percent of respondents also stated that there was a need for greater government incentives to spur renewable energy adoption. The environmental benefits of renewable energy as well as the promise of reducing imports were key reasons that respondents identified for supporting renewable energy (Figure 16). However, there was a lesser inclination towards adopting renewable energy as a strategy for reducing energy costs, indicating that people are not yet fully convinced that the significant reduction in operational costs associated with renewable energy offsets the higher initial investment required for these technologies.

Figure 16: Key Benefits of Renewable Energy as Identified by Respondents

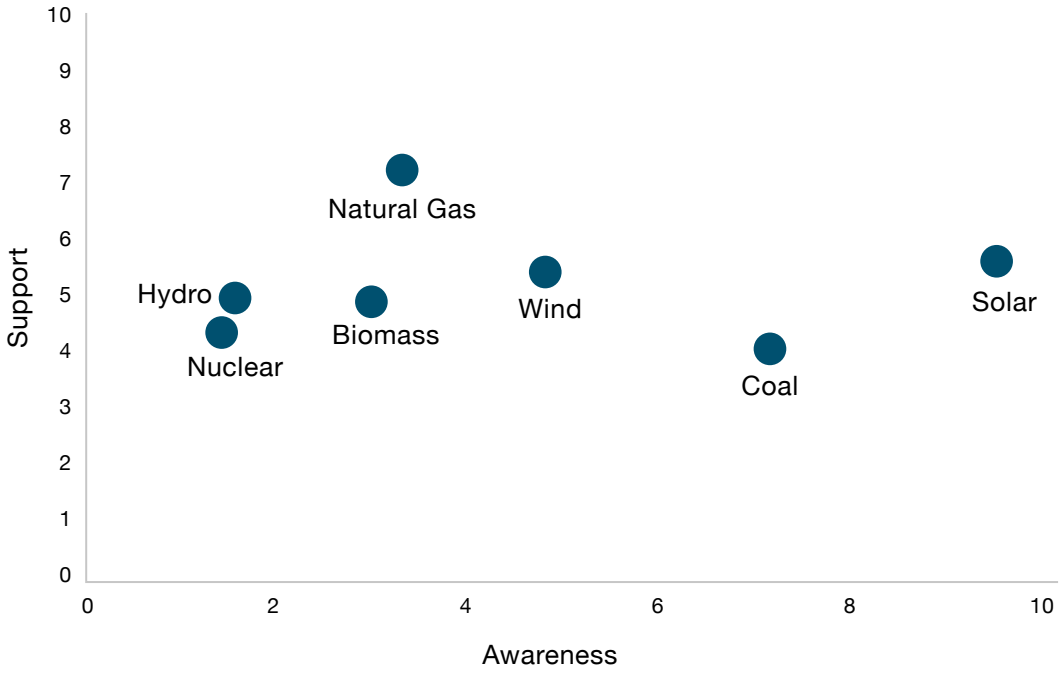


Renewable energy or green energy consists of a broad bucket of technologies, each of which has advantages and challenges. Respondents were asked about their awareness of different energy sources and their support for these sources as a key part of India's future energy basket.

Figure 17 shows the relationship between awareness and support for the different sources. Awareness and support for solar energy was the highest, followed by wind energy. This result is unsurprising, as these two technologies have gained increased acceptance due to technological advancements and are recognised as

pivotal elements of India's as well as global energy transition. While awareness of coal as an energy source was widespread, support for it was low, although not absent, with 40 percent of respondents who were aware of coal expressing their continued support for it as a future energy source. This suggests that many citizens still perceive coal as a significant component of India's energy mix, despite its high marginal emissions. Conversely, support for natural gas as an energy source was remarkably high, with 73 percent of respondents who were aware of natural gas strongly expressing their support. This finding is unexpected, given the historically limited role of natural gas in India's energy mix. This implies that citizens view natural gas as a vital fuel for the future and a crucial element in India's energy transition, further substantiating the notion of natural gas as a valuable transitional fuel during the shift towards cleaner energy sources.

Figure 17: Awareness and Support of Green Energy Sources*



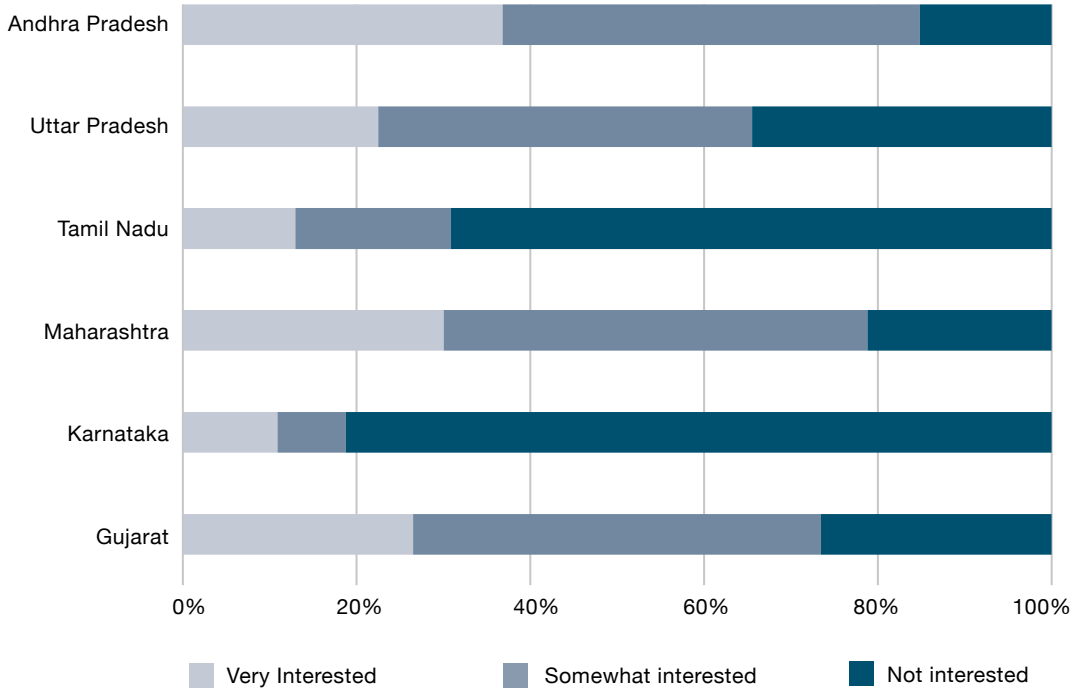
**The axes represent a 10-point rating scale.*

d. Willingness to shift to renewables

The adoption rates in the survey are consistent with the prevailing understanding of the limited uptake of RTS in residential settings. Additionally, the survey examined various factors related to the inclination to transition among respondents who are currently not using renewable energy.:

- Overall, there was substantial interest across respondents to adopt renewable energy. Around 60 percent of respondents (602 respondents) expressed some level of interest in adopting renewable energy, with 25 percent expressing a strong desire to adopt. However, there were substantial differences across states; respondents from Karnataka and Tamil Nadu exhibited the lowest willingness to adopt, with the majority expressing no desire to transition to renewables. It is noteworthy that these two states are leaders in utility-scale solar and wind energy installations, although their performance in residential renewable rooftop solar has been subpar.
- Respondents were asked about their preferred mode of switching to renewable energy. Overall, there was an even distribution across respondents preferring to install RTS systems and those who would prefer to purchase renewable electricity from the grid, with 35 percent of respondents choosing either of these options. However, in Maharashtra and Gujarat, the majority of respondents expressed a preference for setting up their own RTS systems. These two states are also at the forefront of RTS adoption, with electricity utilities and state governments actively promoting the uptake of RTS. This finding suggests that the existing rates of adoption and proactive state policies play a significant role in enhancing the willingness of potential users to shift to renewable energy solutions.
- Green premiums on purchasing renewable energy from the grid have been considered by some states. While our findings indicate that purchasing renewable energy from the grid is a popular choice for switching to renewable energy, the appetite to pay an additional premium for this energy remains low; only 24 percent of respondents were willing to pay a higher tariff to purchase renewable electricity from the grid. In particular, the willingness to pay the green premium was very low in Maharashtra, with only 16 percent of respondents from the state agreeing to pay the premium. This is notable since, in Maharashtra, the State Electricity Regulatory Commission had proposed a green premium of INR 66 per unit of green power. The survey findings suggest that there may not have been widespread support for the state's green premium policy.

Figure 18: Willingness to Shift to Renewables



e. Barriers to adoption

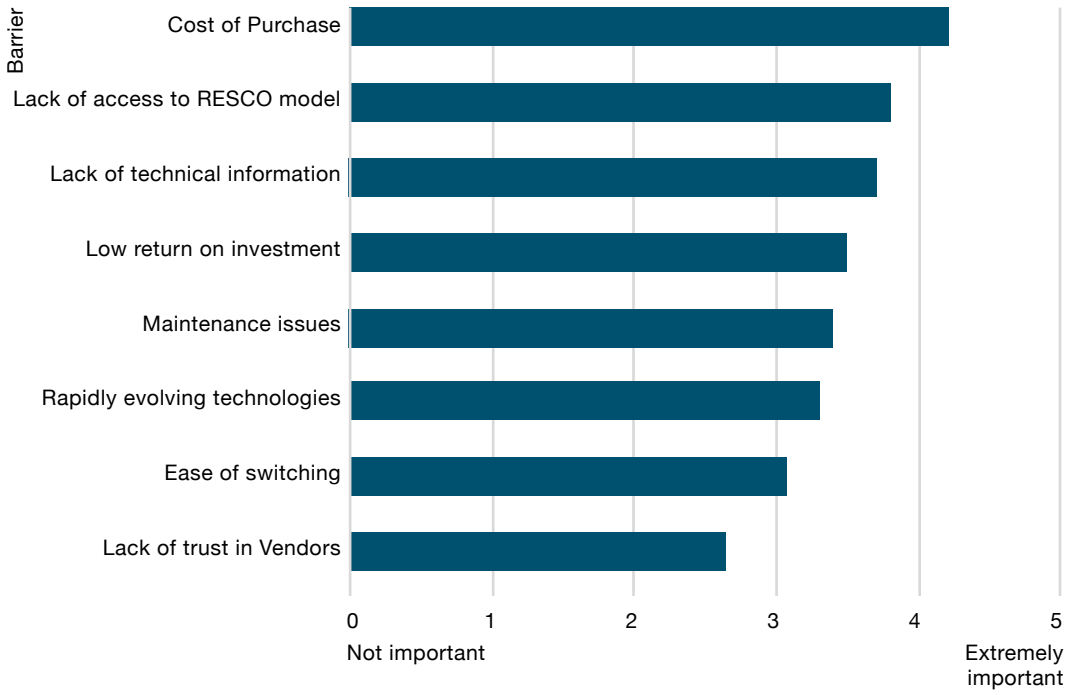
Having assessed the perception and willingness to shift, respondents were asked to rate how important specific barriers were to their decision to adopt rooftop solar (Figure 19):

- Financial barriers remain the most important barrier to RTS adoption. The high upfront costs as well as the perceived low return on investment were given the highest scores in terms of their importance in respondents' decision to adopt RTS. Lack of access to OPEX-based financing models was also given high scores, underscoring the need to extend these models to a wider base of residential consumers. These results also align with the experience of existing RTS users, who identified financing as a key challenge for RTS adoption.
- Lack of awareness was also a key issue identified by respondents. The constantly evolving nature of these technologies, coupled with the availability of multiple options, presents a significant challenge. Many respondents expressed difficulties in identifying the most suitable technology, which

remains a major barrier to adoption. Moreover, consumers still lack knowledge about vendors that offer RTS solutions and the various business models available for adoption. Although there has been a noticeable increase in the willingness to adopt, there is a pressing need to provide more information about the actual adoption processes.

- Unlike the C&I segment, there are substantial subsidies available both at the Central and State levels. Among the states considered in our study, Gujarat and Tamil Nadu provide state-specific subsidies in addition to the central subsidies for residential consumers up to 40 percent of the cost of the system. However, our survey indicated that awareness of these subsidies and means for accessing the subsidies remains low among respondents. Across the states, 56 percent (572 respondents) of the sample stated that they were not aware of government subsidies available for RTS adoption. The awareness levels were also not substantially higher for states which had state-specific policies. This suggests that there is an urgent need to improve awareness related to subsidies and the procedures for availing these. The National Solar Rooftop Portal is a major step towards easing the processes for residential consumers. However, there is a greater need to increase the awareness of these tools, possibly through greater on-ground engagement and awareness building.

Figure 19: Barriers to RTS Adoption for Residential Consumers



Policy Implications and Recommendations

The survey explored multiple aspects of renewable energy adoption from the perspective of consumers. This section delves into the policy implications derived from key insights obtained through the survey, policy analyses, and stakeholder consultations. We have also identified specific recommendations aimed at overcoming some of the obstacles that impede the widespread adoption of decentralised renewable energy solutions.

Study Insight: While there was significant understanding of the processes and procedures for installing RTS, awareness levels related to the financial implications of RTS adoption remain low across consumer segments.

Recommendations:

- **Extending the scope of existing awareness tools to the C&I segment:** MNRE recently took several steps to simplify the procedures for residential consumers, with the development of a national rooftop solar portal. Residential consumers can utilise this portal to apply for RTS, obtain technical feasibility approval, and identify the right vendor and technical specifications of the solar modules. A similar portal is required for C&I consumers. In addition to existing features, C&I consumers could benefit from information regarding vendors providing OPEX models for MSMEs as well as financing institutions best prepared to support MSME borrowing.

- **Improved information dissemination:** There is also a need to improve the knowledge of existing tools through on-ground awareness programmes in specific industrial clusters and residential colonies. Pilot projects in certain industrial clusters could also have a catalytic effect on adoption if the financial benefits and operational procedures from the pilot are well documented and disseminated to other similar clusters.

Study Insight: Power cuts continue to hamper the operations of industries and lead to heavy dependence on polluting diesel-based backup sources, particularly for C&I consumers.

Recommendations:

- **Establishing RTS as a reliable source of power:** Survey findings reveal that the utilisation of backup electricity sources is concentrated during daylight hours. Moreover, the intensity of the use of backup sources is such that rooftop solar could play an important role in reducing dependence on these sources. There is a need to improve awareness among C&I consumers for RTS as a solution to resolve the impediments associated with the present combination of grid electricity and DG sets.

- **Emphasising the financial benefits of RTS:** There is a need to emphasise the financial advantages of rooftop solar, both in terms of cost reduction from grid electricity and decreased expenses on DG sets. Undertaking a comprehensive study to analyse the utilisation of DG sets for MSMEs and to outline the financial and environmental savings derived from wider RTS adoption and DG set replacement would be a valuable undertaking.

Study Insight: Receptiveness towards RTS is high among all consumers, but willingness to pay remains low.

Recommendations:

Several studies have indicated the long-term financial benefits of RTS systems. However, the high upfront costs, particularly in CAPEX-based models, mean that the payback period for RTS is long and depends on the intensity of usage. This, combined with reliability concerns, means that, while consumers are willing to adopt RTS, their willingness to pay remains low.

- **Reconsidering green premiums:** Renewable energy makes up a larger share of grid electricity. Some states have considered green premiums on grid tariffs for renewable energy usage, but our findings suggest a low appetite for such an approach. Instead, DISCOMs should look at time-of-day tariffs to help consumers tailor their electricity-usage timings to account for periods of excess renewable capacity in the grid. This will help DISCOMs

better integrate renewable electricity into the grid while also allowing greater utilisation by consumers.

- **Innovative financing mechanisms:** The cost of financing for RTS is also high, particularly for residential consumers and SMEs. Our survey results indicate that loan availability and high-interest rates pose serious challenges. The perceived higher risk associated with smaller consumers has deterred financial institutions from showing interest in this segment. To address this issue, state governments can collaborate with public sector entities like Convergence Energy Services Limited (CESL) and Energy Efficiency Services Limited (EESL), as well as international development banks to establish risk guarantee mechanisms. These mechanisms would enable the sharing of non-payment risks between financial institutions providing loans for RTS users and the entities.

Study Insight: The high upfront costs and lack of robust financial incentives remain the biggest perceived barriers to RTS adoption, especially for C&I consumers.

Recommendations:

We have identified two primary reasons for the lack of subsidies for C&I consumers—the prevailing perception that C&I consumers are more financially capable than residential consumers and the heavy dependence of DISCOMs on C&I consumers for revenue, making any large-scale shift away from grid electricity potentially detrimental to DISCOM health. There is substantial scope to develop mechanisms where DISCOMS can benefit from adoption in these segments. While a wholesale shift for large-scale consumers might impact DISCOM finances, a shift from smaller electricity consumers could benefit DISCOMs through reduced distribution losses while also helping them meet their renewable purchase obligations. There is a need to acknowledge all the system benefits that RTS can offer to DISCOMs and increase the performance-based financial incentives provided to them.

- **Dual subsidy for consumers and DISCOMs:** There is scope to have a dual subsidy for C&I consumer uptake. Under this system, consumers would receive a subsidy for adopting RTS, while DISCOMs would receive an additional incentive for meeting a specific portion of their Renewable Purchase Obligation (RPO) targets through increased RTS adoption in the C&I segment. To ensure the efficient allocation of public funds, this subsidy could be targeted toward specific industries based on factors such as the

size of RTS installations or other indicators related to revenue and assets. The current incentives provided to DISCOMs are aimed to increase their administrative efficiency to deploy RTS; however, these incentives are insufficient. The amount of incentivisation should be reflective of the losses and costs incurred by the DISCOMs because of RTS adoption and the costs of any investment in upgrading infrastructure and the digitalisation of data.

- **Utility-centric business models for RTS adoption:** The most active intervention could be to encourage a utility-led deployment model where DISCOMs act as an active intermediary in the transactions between the developer, customer, and financial institutions. This helps reduce the risk of default from the perspective of the developer and financiers and eases the procedural burden for consumers, allowing them to pay for the RTS through convenient EMIs factored into their monthly electricity bills. The DISCOMs benefit through recouping additional fees and business gains as part of the transaction while also reducing losses from net metering and distribution.

Study Insight: The electricity consumption patterns of MSMEs make them relatively more suitable for adopting RTS. RTS could be an effective way for MSMEs to lower production costs, since electricity is a major input in their production processes. However, MSMEs may be hesitant to invest in renewable energy technologies due to uncertainties about their performance, compatibility with existing infrastructure, and negative perceptions of the long-term cost benefits.

Recommendations:

- **Expanding the scope of solar policies:** National and state solar policies should have a clearer focus on MSME RTS adoption. States should include specific targets for RTS adoption in the C&I segment. Considering the potential for RTS in this segment, there is a strong case to provide targeted subsidies for MSMEs, given that the high upfront costs remain the biggest challenge for this segment.
- **Cluster-based approach:** Given the heterogeneous nature of different industries, the key barriers faced by MSMEs could be best resolved through a targeted support program focused on specific industrial clusters. Industrial clusters gather similar MSMEs operating within a particular sector in a single location, enabling enhanced demand aggregation and targeted interventions in areas such as knowledge sharing, collaboration, and improved financial services. India has over 6,500 MSME clusters and around 400 industrial

clusters. A national MSME cluster-based RTS program could focus on identifying a set of 10–20 clusters covering industries that are suited to RTS adoption. Based on our analysis, we have identified machinery manufacturing, textile production, pharmaceuticals, and automobile parts manufacturing as potential frontrunner segments. These segments have been selected based on their electricity consumption patterns, receptiveness to adopting renewable energy technologies (such as RTS), and the potential financial benefits they could derive from such adoption. The focus of such a programme could be informed by previous efforts, such as those implemented for energy efficiency by the Bureau of Energy Efficiency, and can focus on three core areas: i) Power consumption and technology analysis to identify the potential for switching to RTS, including as a means to reduce dependence on backup power sources; ii) Capacity building to help SMEs identify RTS technologies and assess financial implications of different business models; and iii) Facilitating innovative financing mechanisms through demand aggregation and connecting small industrial units with banks such as SIDBI and international agencies such as the World Bank to identify and implement mechanisms for funding collaterals associated with rooftop solar.

- **Improve ease of obtaining necessary permissions and procedures for adopting RTS:** To promote investment in RTS by the MSME segment, it is necessary to simplify administrative procedures and decrease the number of factors that need to be considered when making investment decisions regarding the adoption of RTS. The aim should be to reduce paperwork and minimise interactions with consumers. The simplification of administrative procedures can be initiated by simplifying the forms and standardising the approvals required. The process of obtaining approvals varies from state to state, and even within a particular state, the approval process is not standardised. Additionally, the absence of well-defined timelines for processing approvals by the diverse agencies involved often leads to prolonged delays, particularly in cases involving net metering. It is imperative to establish a standardised framework for approvals, ensuring consistency across states, while also implementing clear and defined timelines that must be strictly adhered to.

Study Insight: Acceptance and willingness to adopt the OPEX or RESCO-based financing model remain limited due to lack of awareness and accessibility.

Recommendations:

The OPEX or RESCO-based business model benefits consumers, since the capital expenditure for installing RTS is taken on by the developer, and the consumer only has to pay a tariff based on their usage. However, this model is largely limited to large-scale C&I consumers with greater bankability and the ability to fulfill long-term contracts. Smaller customers such as SMEs and individual residential consumers find it difficult to access these models due to poorer credit ratings, which increases the payment risk for developers. This poses a dual problem, since these smaller customers are also the ones that cannot afford the higher CAPEX payments needed to install RTS and could benefit the most from these models.

- **Reducing risks for developers:** Government agencies and developers can work with financial institutions such as national development banks to identify risk guarantee mechanisms that can allow developers to reduce their risks and exposure by extending the OPEX model to smaller consumers with riskier credit profiles. For example, national development banks and international financing agencies can consider setting up a fund that can be used to provide risk guarantees for lenders in case of defaults by developers engaged in providing OPEX models. There is also scope to look into concessional loans to developers to encourage them to expand their RESCO business.
- **Exploring the green bond market:** Green bonds can potentially be utilised as a funding source. State or municipal governments can establish special purpose vehicles (SPVs) to raise debt from the green bond market, supported by cash flows generated from rooftop solar projects. Subsequently, the SPV can collaborate with developers to extend RESCO-based business models to specific SMEs or residential consumers.

Study Insight: Benefits from net metering are difficult to access for both residential and C&I consumers due to technical limitations and procedural uncertainties.

Recommendations:

- **Streamlining net-metering regulations and procedures:** The approvals needed for net-metering should be standardised, and clear timelines should be defined and implemented. Even if uniform regulations across states may not be desirable, regulations could be formulated considering state-level nuances, characterised by factors such as the strength of distribution utilities. A primary solution to minimise the regulatory burdens and procedural complexities is to institutionalise a single-window facility for the entire ecosystem of rooftop PV deployment that includes encompassing connectivity, net metering, electricity inspection, and limitations on sanctioned load.

- **Expanding virtual net metering and group net metering:** The conventional net-metering framework maps one consumer to one point of generation. This makes it difficult for large commercial establishments like the Indian Railways or even residential consumers in housing societies with limited space to avail the benefits of net metering. This is also highlighted in our study findings, as many respondents reported physical constraints as a key impediment to adoption. However, customers who have multiple buildings and service connections can make use of surplus solar energy generated in one property to meet the electricity needs of another property, as long as these connections are within the territory of the same distribution company (DISCOM). This arrangement is possible through virtual net metering and group net metering.

  These progressive net metering arrangements allow RTS users who produce excess energy in one location to distribute it to other properties. They also enable customers to enjoy the advantages of net metering even if they are not physically present at the site of energy generation. Additionally, they facilitate the establishment of jointly owned onsite or offsite renewable energy systems, thereby broadening the scope of net metering benefits to a larger group of consumers. This is particularly advantageous when

there is limited roof space or electricity service connection constraints in one of the properties. These net-metering arrangements can be adopted by organisations that lease premises and are constrained by issues related to landowner permission for onsite RE systems. Consequently, consumers who are based away from the point of generation can claim the benefits of renewable energy.

The Delhi Electricity Regulatory Commission (DERC) has pioneered the Group Net Metering and Virtual Net Metering structure under the DERC Regulations, 2014. The Group Net Metering Framework is designed to apply to all customers in the NCT of Delhi. The administration has established a minimum project capacity of 5 KW, while the maximum capacity allowed at a single location is 5 MW. Additionally, the Virtual Net Metering Framework is intended for use by residential consumers, housing complexes, government offices/local authorities, and solar energy providers who are registered under the Act.

States must increasingly look to include virtual and group net metering as a key part of their net metering regulation and expand the scope of these regulations so that these arrangements can also be utilised by C&I consumers. Furthermore, there is a need to build awareness around utilising these arrangements as a solution to the physical constraints that hamper RTS adoption.

Conclusion

As India looks to scale up decentralised renewable energy, this study has highlighted some of the key challenges and opportunities based on a ground survey of different consumer segments. While there exists strong policy support for RTS adoption, consumers continue to face informational, technical, and financial barriers that impede adoption.

For C&I consumers, this study is unique in implementing a systematic and representative assessment of renewable energy adoption patterns and perception across different industry sizes and types across six states. Our findings suggest that small and medium industrial units have electricity consumption patterns that could be well suited to RTS adoption. The higher share of electricity cost in their total operational expenditure also means that they could benefit greatly from the long-term cost benefits of rooftop solar.

Moreover, C&I consumers continue to suffer from power cuts and unreliable power supply from the grid, hampering business operations and increasing power costs through heavy dependence on DG sets. Our survey reveals that these power cuts are largely concentrated during daylight hours, suggesting that a switch to rooftop solar could be useful in resolving reliability issues while also bringing down energy costs. However, SMEs still lack a clear understanding of the possible cost benefits of adopting RTS. These consumers are also perceived to be high risk by financers and developers, which hampers their ability to access OPEX-based business models. This could be the driving factor behind most respondents stating that they were willing to adopt RTS but are unwilling to pay the extra costs associated with adoption.

An analysis of the available incentives at the central and state level also reveals a lack of financial support for the C&I segment, with most incentives focused on residential consumers. The higher tariffs paid by these consumers

also mean that DISCOMs depend disproportionately on these consumers for their revenues, creating few incentives for them to aid in their switch to rooftop solar. To resolve these issues, we propose several recommendations related to awareness building around the financial benefits of RTS and devising innovative financial instruments and deployment models which can reduce risks for investors while creating the right incentives for DISCOMs to prioritise RTS adoption in the C&I segment.

Among residential consumers, the survey revealed very low adoption of rooftop solar, with less than 1 percent of respondents utilising these technologies. This is in line with the broad finding that India still has a long way to go to realising the immense potential of residential RTS. To be sure, there is widespread support for renewable energy, with solar energy receiving the greatest support for its perceived environmental benefits and the promise of reduced imports through homegrown energy generation. However, much like the C&I segment, residential consumers reported a high willingness to adopt rooftop solar but a very low willingness to pay. Moreover, awareness about the availability and the benefits of different business models for solar adoption was also low. Financing was also identified as a key barrier to adoption, with many respondents stating that they were not aware of the available government subsidies for RTS adoption and did not know how to access affordable financing for these technologies. This highlights the need for greater awareness building around the cost benefits of rooftop solar and the means for availing government subsidies.

Overall, the study highlights that with the right kind of support, there is substantial willingness on the part of both residential and C&I consumers to adopt rooftop solar.

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